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The WELDING Journal

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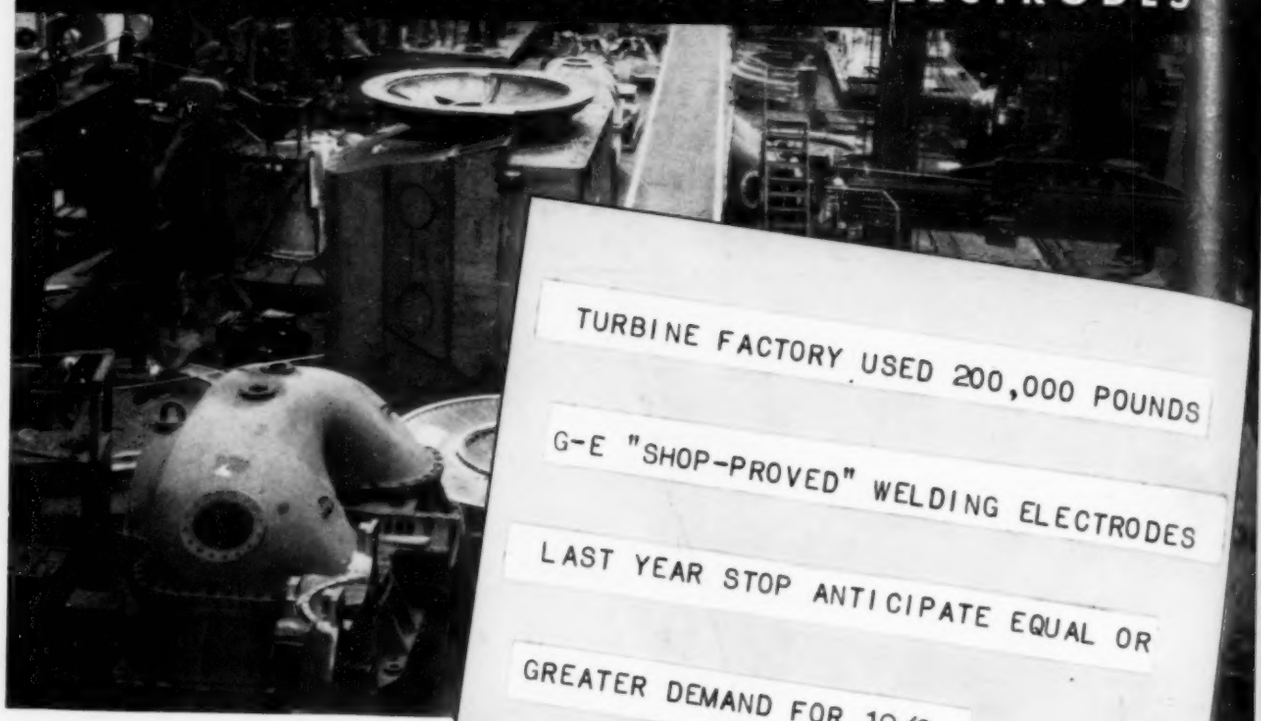

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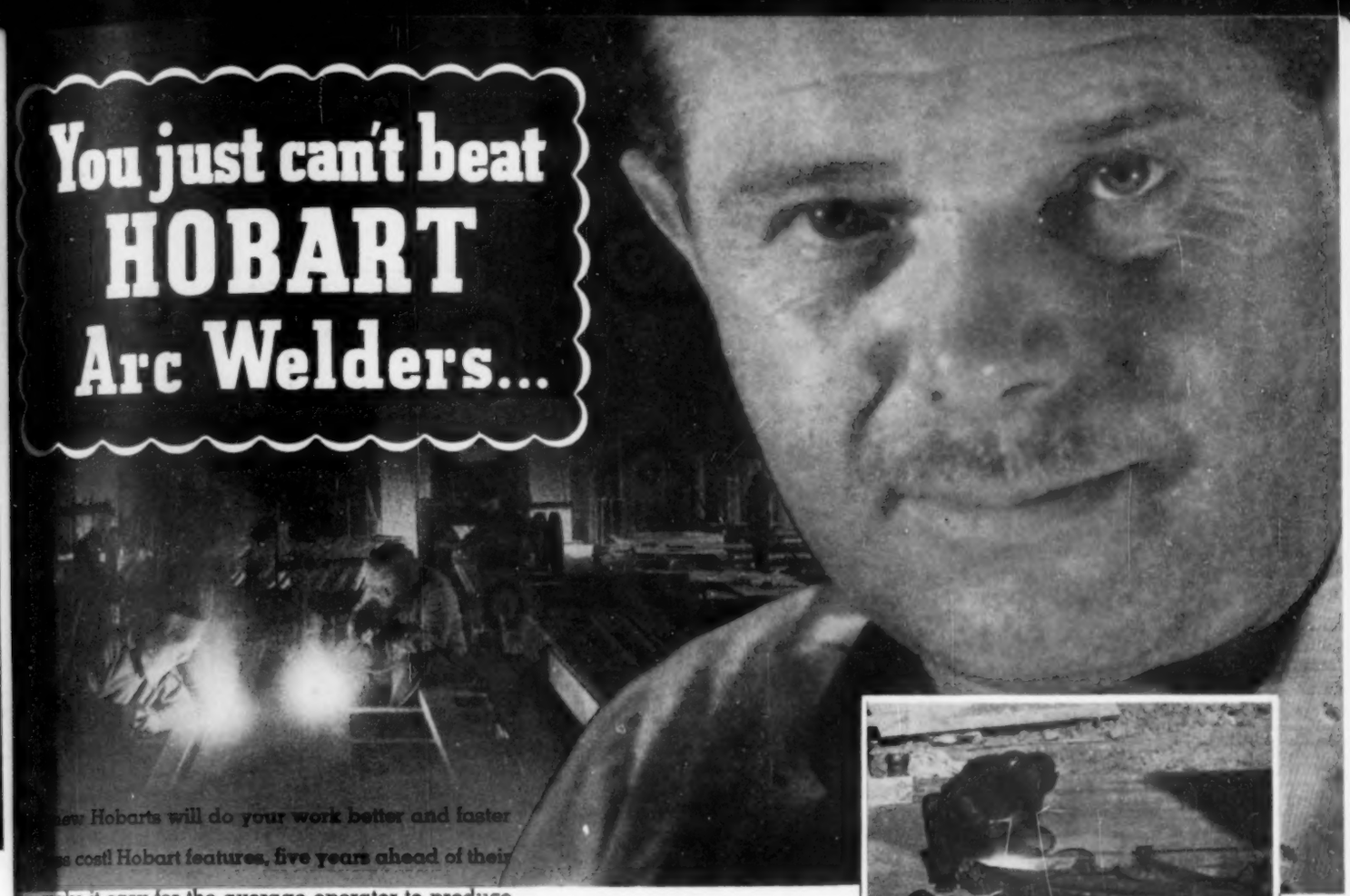

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OXYACETYLENE SPROCKET-CUTTING

Machine of New Design Eliminates Variation in Pitch and Other Errors*

By ARTHUR B. JONES†

TO ENTER into the field of sprocket-cutting machinery with an all-welded product, it was necessary not only to accomplish precision cutting, but to eliminate variation in pitch and other errors caused by expansion and contraction while cutting. This was accomplished by the machine described here (see Fig. 1). The machine was designed, fabricated and used in the welding department of a manufacturing plant.

The oxyacetylene sprocket-cutting machine consists of a table mounted on four legs having an indexing head and an adjustable base upon which is mounted a camograph.

The indexing head is at one end of the table in line with the slot by which the camograph is located. It consists of a vertical shaft resting in ball bearings and extending both above and below the table. The section above the table is constructed so that a blank having a $1^1/_2$-inch hole drilled in the center can be clamped securely to the shaft. Below the table an index plate is bolted and keyed to the end of the shaft.

The index plate is stopped by a plunger, located at one side, having a strong spring behind it and tapered to fit the notches in the plate. This serves to hold the blank rigid while the camograph cuts the indentation of one tooth. The plate is then indexed to another notch and the operation repeated. The camograph base travels on ways and is adjusted by means of a long thread screw and a hand wheel at the back of the table.

The design was greatly simplified by use of arc welding and gas cutting. The table top was cut out of $1^1/_4$-inch plate steel and had pads welded to the top and bottom to give bearing surface for the camograph base and to reduce machining to a minimum.

The legs were fastened by welding pipe couplings to the under side of the table and threading one end of the pipes that were used as legs. This allowed compensation for irregular floor by screwing in or out one or more of the legs. Bosses were welded to the table to hold the ball bearings and the index shaft in place. The camograph base was carved out of steel slab also and welded complete.

The device for tripping the plunger when indexing the blank is of welded construction and was welded to the machine after it had been assembled. The plunger is tripped by a cam operating on a shaft and turned by a lever flush with the top of the table.

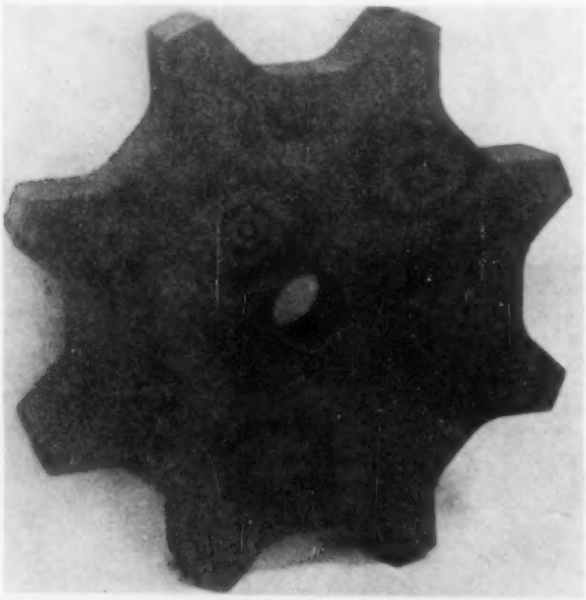
All parts for the oxyacetylene sprocket-cutting machine were carved out of steel slab by the oxyacetylene process at a cost of $13. The time required to design, assemble and weld amounted to $40. Labor cost for machining was figured without burden, the machine being a factory job, and totaled $150. All material added to $32, making a total cost for the machine, exclusive of the

Fig. 1—Oxyacetylene Sprocket-Cutting Machine of Arc-Welded Construction

* Brief of Award Paper from The James F. Lincoln Arc Welding Foundation, Cleveland, Ohio.

† Assistant Foreman of Welding Department, Jeffrey Mfg. Co., Columbus, Ohio.

Fig. 2—A Sprocket Center Cut on the Arc-Welded Oxyacetylene Cutting Machine



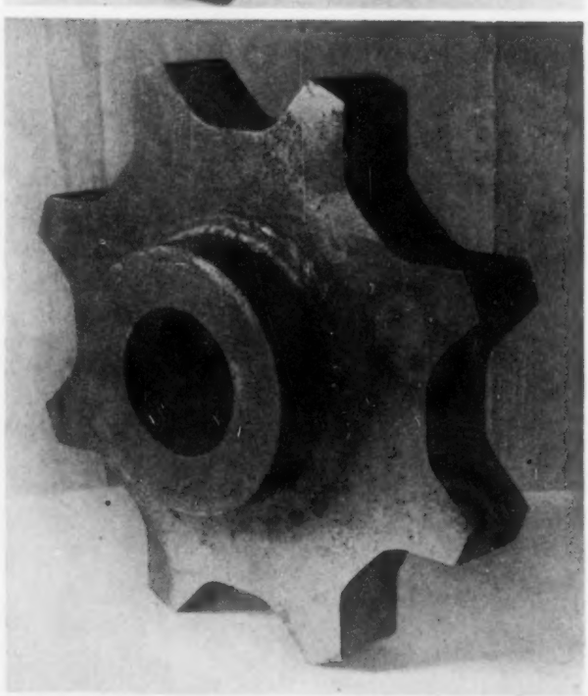


Fig. 3—Hub Welded to Sprocket Center

camograph, of $235. The camograph was used because it was available and can be changed to its former mounting very readily.

First the sprocket blank was cut out of slab steel, of the required thickness and S. A. E. specification, by use of the oxyacetylene cutting torch. The blank was cut to the correct outside diameter.

A one and one-half inch hole was then drilled in the center of the blank for mounting on the oxyacetylene sprocket-cutting machine. When the blank had been mounted on the sprocket-cutting machine the camograph was set up to the bottom diameter of the tooth. The set-up required very little time due to the fact that the camograph moved, by screw adjustment, in line with the blank. The cam is so made that the cutting torch will cut the indentation of one tooth. By indexing the blank after each tooth has been cut, and going to the opposite side, it is possible to cut all of the teeth the same and have a minimum variation in pitch.

Figure 2 shows a sprocket center that has been cut on the oxyacetylene sprocket-cutting machine. This sprocket was carved out of S. A. E. 1035 steel and a smooth cut was obtained on every tooth. The hubs were then welded to the sprocket center. The hubs were also cut with an oxyacetylene cutting torch.

In Fig. 3 is shown a carved weld sprocket ready to leave the welding department to be bored and chamfered.

Cost will be presented of both large and small sprockets. The small sprocket does not quite reach the minimum size sprocket that can be cut and the large one does not represent the maximum size. The small sprocket that was chosen has an outside diameter of $11\frac{5}{8}$ inches and the plate center is $1\frac{3}{4}$ inches thick.

Material	$2.62
Cut blank	
Cut hubs	
Cut teeth	1.08
Oxy. consumed	0.50
Act. consumed	0.08
Weld hubs	0.72
Drill	0.28
Chamfer	0.45
Total	$5.73

The cost compared very favorably with the cost of a cast steel sprocket. Figuring the cost of a cast steel sprocket with a weight of 60 lb., at $14\frac{1}{2}$ cents per lb., we arrive at a price of $8.70, showing a saving of more than 20% in favor of the oxyacetylene machine cut and welded sprocket.

In the case of the larger sprocket the saving was even greater. The sprocket has an outside diameter of 37 inches and the plate center is also $1\frac{3}{4}$ inches thick.

Material	$25.00
Cut blank	
Cut hubs	
Cut teeth	1.80
Oxy. consumed	1.50
Act. consumed	0.22
Weld hubs	3.75
Drill	0.28
Chamfer	1.20
Total	$33.75

The cost of a like casting, figured at $10\frac{1}{2}$ cents per lb. and weighing 620 lb., is $65.10, showing a saving of almost 50%. Besides being fabricated of an excellent grade of plate steel which is much superior to a casting of a comparative analysis.

To sum up, when considering the production of sprockets where milled teeth are not required, it is essential that the quality of material and accuracy of dimensions be as high as possible and that the sprocket be economical to manufacture. With the oxyacetylene sprocket-cutting machine described, it is possible to produce sprockets meeting all of these requirements.

PULSATION WELDING BROADENS the Field for Resistance Welding*

By H. C. COGAN† and RALPH S. PELTON‡

THREE factors, namely, *Pressure Density, Current Density* and *Time of Application*, have been used to determine the requirements of resistance welding equipment and the capacity of such equipment to weld a specified job, ever since resistance welding was first used, and up to the present day of Standard and Hi-Production machines.

Within the last few years we have seen the *Pressure* factor developed and subdivided into various methods of automatic application, using motor-driven mechanism, air and hydraulic means, in single and double or two-stage welding pressure application. The latter consists in the application of a light pressure to increase the heating by means of greater surface resistance during the actual passage of welding current, then a quick application of heavy or final pressure during the last stage of heat application and the holding of this final pressure after the welding current has been broken to properly consumate the weld.

Various electronic and sequence welding controls have now been provided for the variations of welding pressure applications, all of which increase the range of resistance welding adaptations.

Welding *Heat* adjustment as generally used today on resistance welding equipment results in the regulation of the amount of current passing through the weld, by either of three methods. Taps on the primary of the welding transformer, an auto-transformer in addition to the welding transformer, or the so-called "phase shift" method through electronic control may be used. Satisfactory adjustment may be obtained by any one of the three methods for the application of a specified welding current to the work under a predetermined single or variable pressure application.

Welding *Time* is varied and controlled by manual, mechanical or electronic means, and in spot welding is usually understood to be the duration of a single application of welding current flow to the work.

In the past it has been common practice for welding operators to "nurse the welding heat along" by manually interrupting the flow of welding current during certain welding operations. Such a practice was of course erratic since it depended on the judgment of the operator and his ability to duplicate the procedure on successive welds.

Today automatic controls are available that will produce an identical series of current application during one automatic machine operation. The purpose of this article is to acquaint the users of resistance welding equipment with the possibilities of an extended field of resistance welding application, that is believed to be impossible without these automatic controls and, further, to

* Series of articles prepared under the auspices of the Publicity Committee, R.W.M.A.
† Chief Engineer, National Electric Welding Machines Co.
‡ General Electric Company.

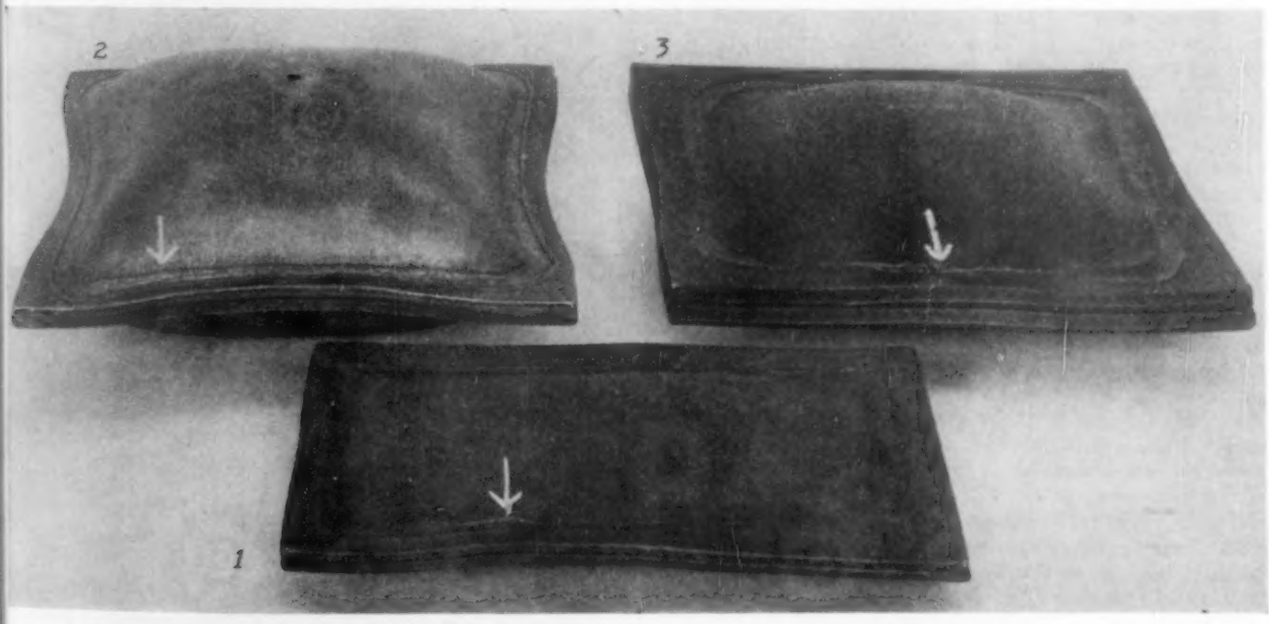


Fig. 1—3 Test Samples of Seam Welds of Steel Plates. Each Broke at Inner Edge of Weld When Inflated by Hydraulic Pressure. 1—Plates 1/16 by 8 by 12 In., Broken at 1400 Lb. Per Sq. In. 2—Plates 1/4 by 11 1/2 In. Square, Broke at 2200 Lb. Per Sq. In. 3—Plates 1/4 by 12 In. Square, Broke at 4500 Lb. Per Sq. In.

Fig. 2—Spot-Welded Steel Sample. 2 Pieces 1 by 3 In. Welded by Interrupted Method. Broke at 118,000-Lb. Load

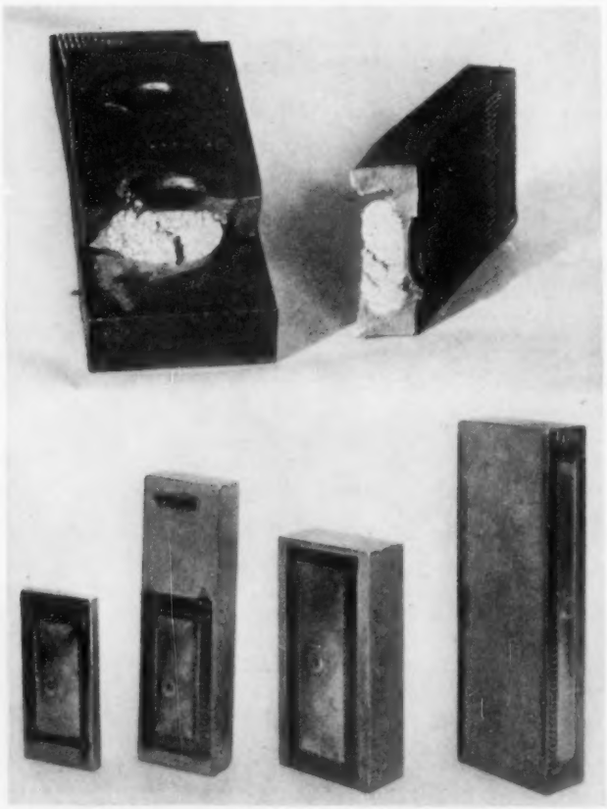


Fig. 3—4 Seam Welds. 0.020-In. to 1/2 In., 0.020-In. to 1 In., 0.020-In. Each Side of 2-In., 0.020-In. Each Side of 4-In. Steel. Failed at 700, 500, 500 and 1300-Lb. Per Sq. In. (Respectively) Water Pressure

increase, by the use of these automatic controls, the capacity of existing resistance welding equipment.

When the periods, during which the flow of welding current is interrupted, are sufficiently long to permit artificially cooled electrodes to maintain their work engaging surfaces below deformation temperatures, while forcing the welding heat to build up between the parts to be welded, we have a new form of welding which has recently attracted considerable attention because of the surprising results obtained therewith. This form of welding has been called "interrupted spot welding" or "woodpecker welding." It is one form of pulsation welding.

Pulsation welding has been used to advantage not only in spot welding but also in line welding, butt welding and projection welding. It may be defined as "a resistance welding method wherein the flow of welding current 'or heat' is applied repeatedly for the making of a single weld, or simultaneous welds, in parts clamped under pressure between electrodes at rest when a single like impulse of the same current is not sufficient to produce the desired weld." When seam welding by this method the usual rolls "or wheels" may be stopped to allow repeated impulses of welding current to make each of the individual welds. This is pulsation roll-step seam welding (Fig. 1). Pulsation projection welding has made a success out of many jobs which otherwise were failures, because of the more favorable rate or method of heating. This is particularly true where several projection welds are made simultaneously.

The advantage of interrupted spot welding is clearly illustrated in spot welding heavy sections. Heretofore, spot welding two pieces of 1-inch plate was not considered a practical operation because of high electrode replacement cost even with the best electrode material, equipment and control (Fig. 2). Usually the electrodes would be damaged because of the intense heat within four or five welds in spite of all water cooling possible and with excellent surface conditions of the work. This made the cost of resistance spot welding this thickness prohibitive in production.

Since the surface of the parts in contact with the electrodes are kept cooler by the interrupted spot welding method, spot welds can be made, successfully, nearer the edge of a part by this method, than by the single impulse method which would result in a splash or squirting of metal. By the same token, narrow strips can be spot welded to other parts with much less deformation.

With interrupted spot welding, two pieces of 1-inch thick plate have been welded with no more electrode tip maintenance than would be used on material 1/8 of this thickness.

The over-all time for pulsation welding may be greater than when using a single application of heat; however, as a general rule, the actual welding time with pulsation welding is so short, compared to single heat application and loading and unloading time, that the same production or time studies used for single heat application usually can be used for pulsation welding.

Pulsation welding has almost unlimited values as to adjustment to suit a particular job. The adjustment of the number of interruptions and the duration of the "off" and "on" times will produce a wide variation of results while

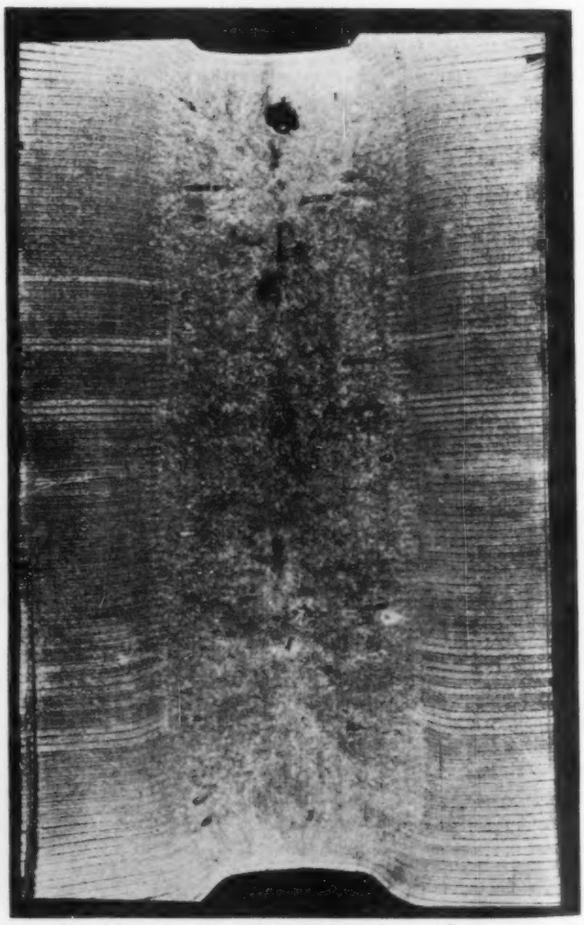


Fig. 4—Spot Weld Through 117 Pieces of 0.044 In. Common Iron After Cleaning Off Scale with Grit Blast

using identical transformer and pressure regulation of the equipment.

An interesting butt-welding cycle (that will be described in detail later) will illustrate the pulsation welding method and show how it can be fitted to the job in hand. Using standard 60-cycle frequency power, the sequence on this job was as follows: 5 cycles "on," 5 cycles "off," 10 cycles "on," 5 cycles "off," 15 cycles "on," 5 cycles "off," 30 cycles "on." The above setting produced uniformly good results on a particular production welding problem and any variation of even one or two cycles of any one of the timing intervals affected the finished weld.

It follows that the total sequence can be progressively increased, decreased or changed up and down or may remain constant—depending upon that required to produce best results.

In general, the use of pulsation welding will make possible the following resistance welds that otherwise would be impractical or impossible:

Spot or seam welding heavy sections with wide variation of the thickness of the two pieces to be welded (Fig. 3).

Spot or seam welding heavy sections of equal thickness.

Spot welding a multiplicity of thin sections, stacked to a thickness heretofore impossible to weld as a production job (Fig. 4).

Projection welding of heavy sections.

Many multiprojection welding jobs.

Butt welding heavy sections without preheating.

Butt welding heavy sections with considerably less flash, loose particles or upset than by conventional heat control.

Increasing the machine capacity in cross section or total thickness that can be welded.

The controls used to obtain pulsation welding (with no change in the welder) can be entirely automatic by use of either the standard electronic sequence controls now available or a motor-driven, adjustable, cam-operated switch assembly.

Equipment will be treated in the next article of this series.

Combine Thermit and Arc Welding in Fabricating Mill Pinion Housing

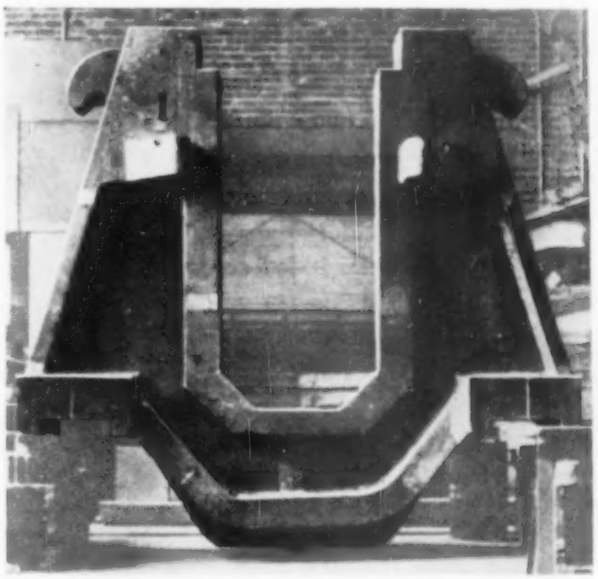
By M. L. SMITH*

BECAUSE of lubrication difficulties experienced with cast-iron housings of blooming mill pinions the Andrews Steel Company, of Newport, Ky., recently evolved a new type of housing fabricated from rolled steel plate by means of welding.

Somewhat unusual in welded fabrication was the combined use of both the Thermit welding process and electric arc welding in the construction of the first of the new type housings. Central members were flame-cut from eight-inch plate in the form of two J-shaped pieces. These two members were then Thermit welded together to make a large U-shaped piece, eight by twenty-seven inches in cross section at the weld. All other members, flame-cut from plate ranging in thickness from one and one-half to eight inches, were welded to the U-shaped central section by means of arc welding.

Heavy mineral coated electrodes, depositing weld metal containing 0.50% molybdenum and having a tensile strength of sixty-eight to seventy-three thousand pounds per square inch, when stress relieved, were used for the electric welding. Joint design included double beveling of all plate edges and the work was positioned so that, with the exception of a few short passes, all welding could be done downhand.

All of the work was preheated before the electric welding was started and the entire assembly was kept at two hundred and fifty to three hundred degrees Fahrenheit, during welding. The welding was done continuously, with two to four welders working in three shifts, so that welding of each joint, once started, could be finished without interruption. About one hundred and forty welding hours were consumed, aside from the making of the Thermit weld.



Blooming Mill Pinion Housing Fabricated from Plate by Means of Thermit Welding and Arc Welding

Prior to machining, the entire structure, including bases and caps, which were fabricated separately, was annealed at approximately twelve hundred degrees Fahrenheit.

Procedure followed resulted in warping being held to a minimum, and inspection after heat treatment showed that where misalignment had occurred, it was, in most cases, less than one-sixteenth of an inch.

The fabricated housing, seven feet, ten inches high and eight feet, nine inches wide, weighed, when completed, twenty-two thousand, five hundred pounds, including caps and bases.

Design and construction of the new type housing were done under the supervision of Mr. A. R. Mitchel, Chief Engineer, and Mr. H. Q. Gruell, Welding Supt., both of the Andrews Steel Company.

* Metal & Thermit Corporation, New York, N. Y.

SHEAR TESTS OF PLUG AND Slot Welds*

By C. E. LOOS† and F. H. DILL‡

SHEAR TESTS OF PLUG WELDS

THE use of filled plug welds is generally prohibited by the specifications and codes governing the use of welding, but, at the request of the Subcommittee on Workmanship and Technique of the AMERICAN WELDING SOCIETY's Conference Committee on Welded Bridges, tests were planned to demonstrate that, when properly made, the strength and other characteristics of plug welds would justify their application to structures. Over one-half million of such welds have been made by the American Bridge Company, largely in the construction of barges for inland waterways, and these plug welds have been entirely satisfactory in service.

Supplementing this series of tests, two additional groups of specimens were prepared and tested in order to examine the characteristics of slot welds and the behavior of joints connected by both plug welds and fillet welds. The preparation of these specimens and the testing procedure were practically the same as for the plug welds.

PREPARATION OF PLUG WELDS

Over two hundred plug welds were made by an experienced regularly employed welder, using A. S. T. M. grade 15 electrodes. These welds were subsequently tested to determine their soundness and shearing strength.

Four plate thicknesses ($1/4$, $1/2$, $3/4$ and 1 inch) and four methods of making holes (punching, punching and countersinking, drilling and gas-cutting) were investigated. Three sizes of holes, chosen to permit the use of standard size punches, were used with each combination of plate thickness and kind of hole. The countersunk holes ranged in $1/8$-inch increments from a minimum diameter equal to the plate thickness plus $3/16$ inch to $t + 7/16$ inch. The other holes ranged similarly from a diameter equal to the plate thickness plus $5/16$ inch to $t + 9/16$ inch. The test joints were made in quadruplicate. No tack welds were used in their assembly.

One hundred ninety-two of the plug welds were made in the flat position using the following technique.

The arc was carried around the root of the joint and then weaved along a spiral path to the center of the hole, depositing and fusing a layer of weld metal in the root and bottom of the joint. The arc was then carried to the periphery of the hole, and the procedure repeated, depositing and fusing successive layers to fill the hole to the depth required. The slag covering the weld metal was kept molten, or nearly so, until the weld was finished. If the arc was broken, except briefly for changing electrodes, the slag was allowed to cool and was completely removed before restarting the weld.

All the welds except those in the 1-inch plate were made flush with the plate surface. The welds in the 1-inch plate were made only about $5/8$ inch deep by depositing two $1/4$ x 14-inch electrodes in each hole.

The size of electrode chosen for each hole was governed by the hole diameter and the plate thickness. The electrode sizes and the welding current used are shown in Fig. 1. In making these welds the electrode was held in a nearly vertical position, and its maximum deviation from the vertical was never more than 20°.

The twelve vertical position welds were made flush with the plate surface, using $5/32$ x 14-inch electrodes, as follows:

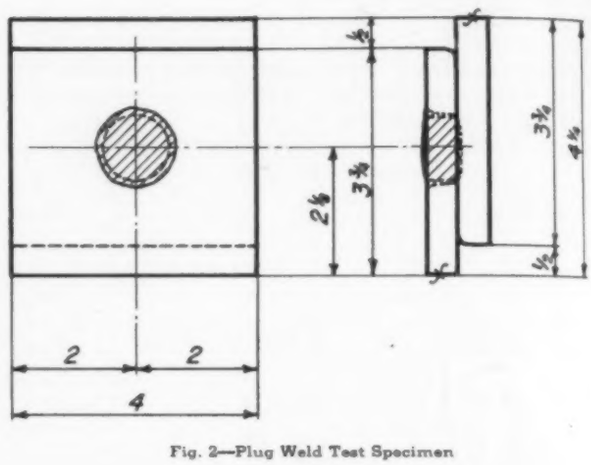


Fig. 2—Plug Weld Test Specimen

* Presented before a Joint Meeting of the New York Section, AMERICAN WELDING SOCIETY and Metropolitan Section, American Society of Civil Engineers, New York, December 20, 1939.

† Carnegie-Illinois Steel Corporation.

‡ American Bridge Company.

ELECTRODE SIZES.

Plate Thickness (In.)	Hole Type	Nominal Diameter of Hole (In.)									
		7/16	9/16	11/16	13/16	15/16	1 1/16	1 3/16	1 5/16	1 7/16	1 9/16
1/4	P D F		5/32	5/32	3/16						
	C	5/32	3/16	3/16							
1/2	P D F				3/16	3/16	1/4				
	C			3/16	1/4	1/4					
	VP	Vertical Weld				5/32					
	VC	"	"		5/32						
3/4	P D F						1/4	1/4	1/4		
	C					1/4	1/4	1/4			
1	P D F								1/4	1/4	1/4
	C							1/4	1/4	1/4	

P - Punched hole.
D - Drilled hole.
F - Gas cut hole.
C - Countersunk punched hole.

Welding Currents Used:
5/32" electrodes, { 200 Amp., Flat position. 150 Amp., Vertical position.
3/16" electrodes, 250 Amp., Flat position.
1/4" electrodes, 300 Amp., " "

Fig. 1—Electrode Sizes and Welding Currents for Plug Weld Tests

Fig. 3—Jig for Testing Soundness of Plug Welds

The arc was started at the root of the joint, at the lower side of the hole, and carried upward along a zig-zag path depositing a layer about $^3/_{16}$ inch thick on the root face and fused to it and to the side of the hole. After cleaning the slag from the weld, other layers were similarly deposited to fill the hole to the required depth.

The welds were made in groups of six, and the test specimens, as illustrated in Fig. 2, were sawed from the joints after the welds were completed. All of the welds in $^1/_4$-inch and $^1/_2$-inch plates were tested to determine their soundness, using the jig shown in Fig. 3. Each specimen was clamped against the open end of the air chamber and compressed air at 85 psi was admitted against the weld face. The edge of the joint was then painted with soapsuds to detect any leakage through the weld. None was found in any weld.

The strength of each weld was measured by testing it to destruction under a shearing load applied in a universal testing machine, using a jig and testing scheme similar to those employed by Mr. G. J. Gibson at Lehigh University in his investigation of plug and slot welds reported in the Supplement to the JOURNAL OF THE AMERICAN WELDING SOCIETY, July 1937. This jig, with specimen in position for testing, is shown in Figs. 4 and 5.

During testing there was no separation of the joint plates before the maximum load was reached and the welds showed remarkable toughness. The welds in the $^1/_2$, $^3/_4$ and 1-inch plate did not fracture completely within the $^1/_2$-inch deformation permitted by the jig and had to be pried apart after they were removed from the testing machine. Figure 6 shows a representative few of the plug welds after testing.

TEST RESULTS FOR PLUG WELDS

Observation of the welding of these plug welds indicates that the necessity for cleaning slag from unfilled holes creates a sharp limit of economy in their use. The maximum amount of metal which can be deposited without removing slag from the holes is about 0.65 cubic inch, and this is equivalent to 0.25 gross pound of electrode. The volume noted is approximately that of the

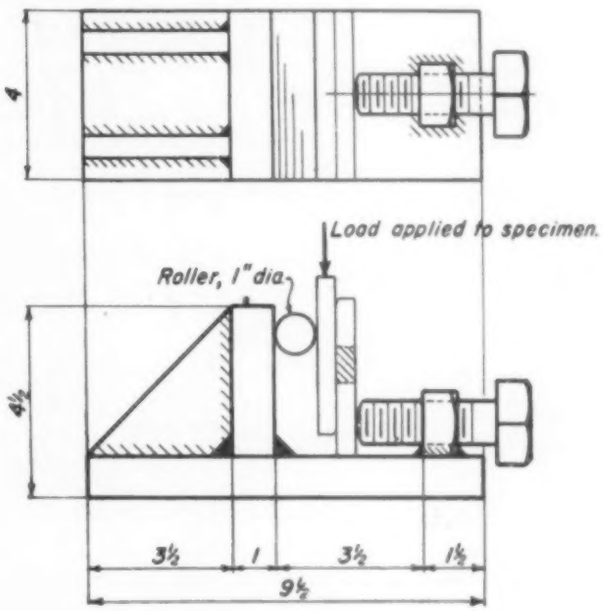


Fig. 4—Jig for Testing Shearing Strengths

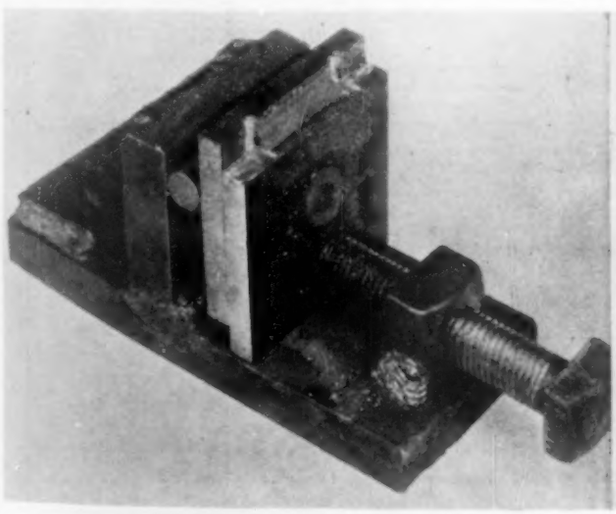


Fig. 5—Jig for Testing the Shearing Strength of Plug and Slot Welds

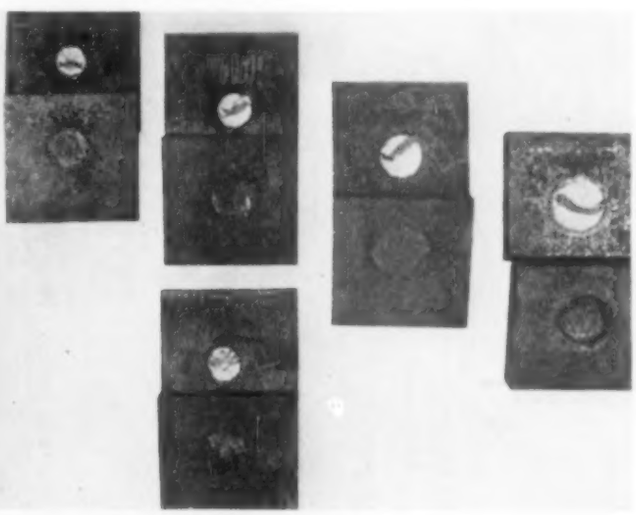


Fig. 6—Plug Weld Test Specimens

full volume of a $^{15}/_{16}$-inch hole in a $^{5}/_{8}$-inch plate, and its gross electrode equivalent represents either one $^{1}/_{4}$ x 14-inch or two $^{3}/_{16}$ x 14-inch electrodes. Thus, when economy is important, the use of completely filled plug welds should be limited to plates $^{5}/_{8}$ inch or less in thickness. Welds in thicker plates should be filled at least one-half of the plate thickness, but the use of plug welds in material over $^{3}/_{4}$ inch thick is generally uneconomical.

The volume of the hole used for a plug weld is the basis for estimating the amount of electrode and the time required to make the weld, because there is ordinarily no reinforcement or overrun of weld size. The gross electrode required for a plug weld is 143% of the weight of steel equivalent to the volume of its hole or the filled portion thereof.

Drilled holes are accurately cylindrical, and their correct volume is readily calculated. Gas-cut holes are generally inaccurate in size and shape, but for their limited use they may be safely considered as cylindrical holes of the dimensions specified. Punched holes are accurate to size at the punch side, but flare to about $^{1}/_{16}$ inch greater diameter at the die side of the plate. Their volume must be calculated as that of the frustrum of a cone, since it will appreciably exceed that of a cylindrical hole of the same nominal size, particularly in thin plates. Countersunk holes are accurate in size and shape, but their volume must be calculated from their actual details. (Punched holes, countersunk from the punch side, will have considerably larger volume than they would have if countersunk from the die side.) The quantities of electrode used corresponded very well with the amount of electrode indicated by calculations based on the volume of the holes.

There were no material differences between the welding times for punched, drilled and gas-cut holes of the same diameter and plate thickness. The countersunk holes, however, because of their larger volume, each required as much or more welding time than was necessary for cylindrical holes in the same plate thickness, but $^{1}/_{8}$ inch larger in nominal diameter. This condition exists even when the countersinking permitted the use of larger electrodes and correspondingly higher welding currents.

Unit Stress Calculated from the NOMINAL Size of the Hole, (p.s.i.)

Plate Thickness (In.)	Hole Preparation	Nominal Diameter of Hole (In.) 7/16	9/16	11/16	13/16	15/16	1 1/16	1 3/16	1 5/16	1 7/16	1 9/16
1/4	P		59 750	52 580	51 830						
	D		50 740	44 170	48 650						
	F		56 820	54 260	50 550						
	C	71 520	65 430	58 890							
5/16	P				53 460	53 180	48 230				
	D				49 820	48 650	48 270				
	F				60 970	51 050	53 260				
	C			56 600	57 360	55 880					
3/8	VP	Vertical Weld				54 230					
	VC	" "			72 290						
7/16	P						56 910	51 360	54 100		
	D						51 280	52 910	55 590		
	F						58 470	56 270	57 800		
	C					60 140	59 940	61 130			
1/2	P								53 920	57 010	64 580
	D								57 360	58 770	59 150
	F								55 590	50 200	52 600
	C							60 540	60 050	60 010	

P - Punched hole, "die side down".
D - Drilled hole.
F - "as cut hole
C - countersunk punched hole, "die side down".

Fig. 7—Average Shearing Strength of Plug Welds (Unit Stress Calculated from Nominal Size of Hole)

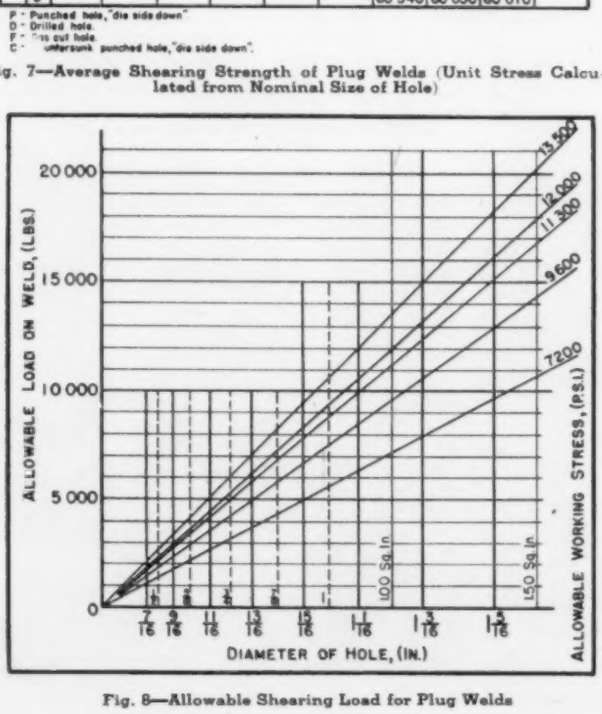
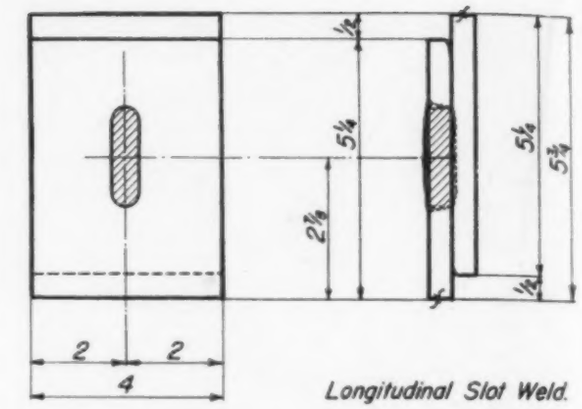


Fig. 8—Allowable Shearing Load for Plug Welds



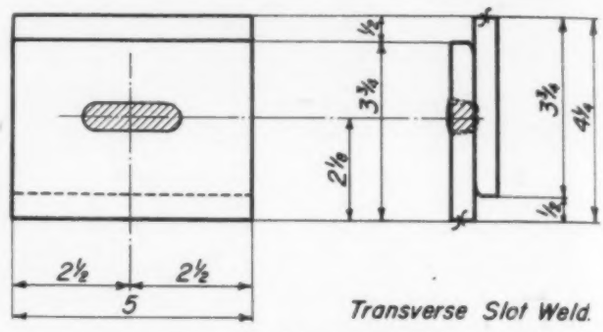
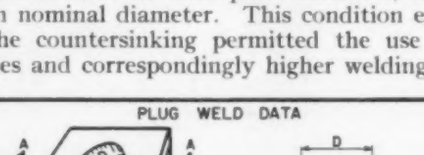


Fig. 10—Slot Weld Test Specimens



PLUG WELD DATA

PLATE THICKNESS T (IN)	MINIMUM SIZE OF HOLE D (IN)	DEPTH OF WELD H (IN)	GROSS ELECTRODE REQUIRED FOR 100 PLUG WELDS. DRILLED HOLE (LBS)	PUNCHED HOLE (LBS)	AVERAGE WELDING CURRENT (FLAT POSITION) (AMP)	WORKING STRESS VALUE @ 13500 p.s.i. (LBS)
5/16	5/16	T	1.90	2.10	200	3300
1/4	5/16	T	2.50	2.80	225	3300
5/16	11/16	T	4.70	5.15	250	5000
3/8	11/16	T	5.60	6.20	250	5000
7/16	13/16	T	9.20	9.90	275	7000
1/2	13/16	T	10.50	11.30	275	7000
9/16	15/16	T	15.70	16.80	300	9300
5/8	15/16	T	17.50	18.70	300	9300
11/16	1 1/16	1/2 T to T	*24.80	*26.20	350	12000
3/4	1 1/16	1/2 T to T	*26.90	*28.60	350	12000
OVER 3/4	T+5/16	1/2 T, MIN.	*FILLED PLUG WELDS, H=T		VERT. & OVD WELDS @ 150A	NOMINAL AREA @ 13500 P.S.I.

Plug welds are not recommended for plates over 3/4" thick.
D = T + 5/16", rounded to next larger sixteenth of an inch.

Fig. 9—Plug Weld Data

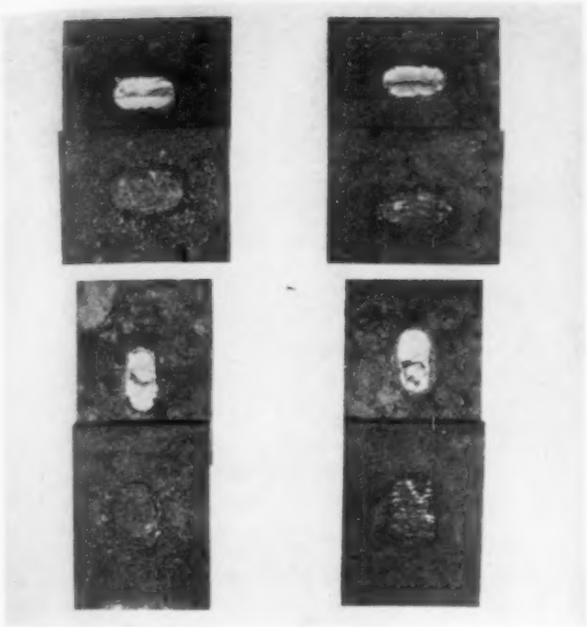


Fig. 11—Slot Weld Test Specimens

Countersinking of holes for plug welds, therefore, does not offer any advantage in economy of electrode or welding time.

Tests of shearing strength of these welds are summarized in Fig. 7. The average of the unit stresses computed from their actual areas of fusion was 53,400 psi, and this strength is also the median of all the test results, which ranged from 44,630 psi to 67,840 psi. Calculations based on the nominal size of the punched, drilled and gas-cut holes gave an average unit stress of 53,970 psi, which corresponds very closely to that calculated from the actual areas of the welds. Calculations based on the nominal size of the countersunk punched holes gave higher apparent unit stresses because these holes were countersunk and fitted "die side down," so that the actual root diameter was $^1/_{16}$ inch greater than the nominal hole diameter, and the fusion area was correspondingly larger. Unit stresses computed from the actual die side dimension (nominal diameter plus $^1/_{16}$ inch) of the countersunk holes, however, agreed quite well with those calculated from the nominal size of the other holes.

The close agreement between the weld stresses calculated from the nominal size of the holes and those calculated from the actual fusion areas indicates that the nominal size of the hole may be safely used in calculating allowable working stresses or strengths of plug welds. Any advantage resulting from the larger die side diameter of plain or countersunk punched holes disappears when the material is punched from the faying surface, as is commonly specified, and their larger diameter should not, therefore, be considered in calculating their strength.

The average shearing strength developed by these plug welds, 53,400 psi, is nearly 90% of the tensile strength required for weld metal by specifications governing structural welding, and the minimum strength recorded, 44,630 psi, is 75% of this value. The minimum strength represents a factor of safety greater than 3 for the maximum working stress ordinarily allowed for shear in fillet welds. The average strength recorded represents a factor of safety of 4, over this working stress. The strengths of these welds, therefore, satisfy the usual requirements for the relation of shearing to tensile strength of material, and they also develop the factors of safety commonly required for the unit stresses used in the design of structural joints. Figure 8 shows the allowable working load for various sizes of plug welds at the unit stresses permitted by common structural welding specifications.

Figure 9 summarizes the data developed by these tests and presents them as information for use in designing plug welds and estimating their cost. The amount of electrode required for other combinations of hole size and plate thickness can be readily determined from the tabulated values given by simple interpolations. Working stress values for other unit stresses than that shown may be determined from Fig. 8.

SLOT WELDS.		Unit Stress Calculated from NOMINAL Size of Slot (p.s.i.)		
Welding Position	Direction of Loading / Size of Slot	$\frac{11}{16} \times 1\frac{1}{2}$	$\frac{13}{16} \times \frac{3}{4}$	$\frac{15}{16} \times 2$
Flat	Longitudinal	52 210	49 520	47 680
	Transverse	56 410	53 820	56 100
Vertical	Longitudinal	55 660	50 060	50 410
	Transverse	51 960	54 900	55 070

Fig. 12—Average Shearing Strength of Slot Welds

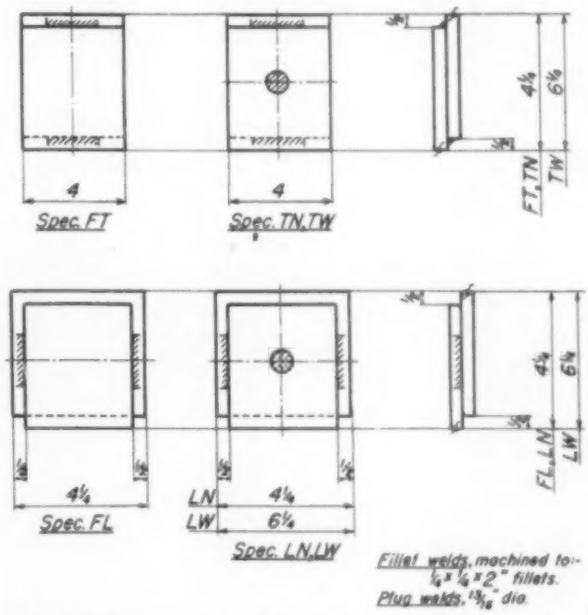


Fig. 13—Specimens for Tests of Plug Welds in Combination with Fillet Welds

PREPARATION OF SLOT WELDS

The slot-weld joints were detailed so that there were eight specimens of each size and type of weld. Four of these were arranged to be tested with the load applied parallel to the weld's longitudinal axis, and four were arranged to be stressed at right angles to this axis. All of these specimens were made of $^1/_2$-inch plate and the welding technique was similar to that used for making plug welds.

The slot-weld specimens were prepared, as shown in Fig. 10, using three sizes of slots punched with standard slot punches. Four specimens for each size of slot and direction of loading were welded in the flat position, using

$^{3}/_{16}$-inch electrodes, and similar sets were welded in the vertical position, using $^{5}/_{32}$-inch electrodes. Each specimen was tested to failure under a compressive shearing load in the jig that was used for the tests of plug welds. No leakage or soundness tests were made of these welds.

TEST RESULTS FOR SLOT WELDS

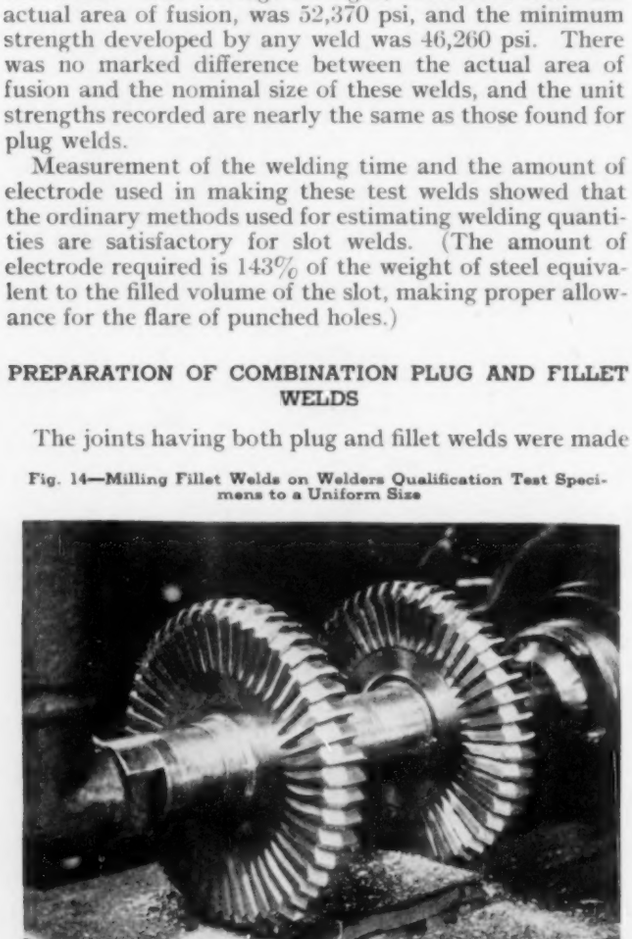
A few typical slot-weld specimens are illustrated in Fig. 11. The results of the test of slot welds are listed in Fig. 12, and they indicate that the conclusions drawn from the tests of plug welds are entirely applicable to slot welds. The relation between the direction of loading and the axis of the weld had no effect on the strength of the welds. The average strength, calculated from the actual area of fusion, was 52,370 psi, and the minimum strength developed by any weld was 46,260 psi. There was no marked difference between the actual area of fusion and the nominal size of these welds, and the unit strengths recorded are nearly the same as those found for plug welds.

Measurement of the welding time and the amount of electrode used in making these test welds showed that the ordinary methods used for estimating welding quantities are satisfactory for slot welds. (The amount of electrode required is 143% of the weight of steel equivalent to the filled volume of the slot, making proper allowance for the flare of punched holes.)

PREPARATION OF COMBINATION PLUG AND FILLET WELDS

The joints having both plug and fillet welds were made

Fig. 14—Milling Fillet Welds on Welders Qualification Test Specimens to a Uniform Size



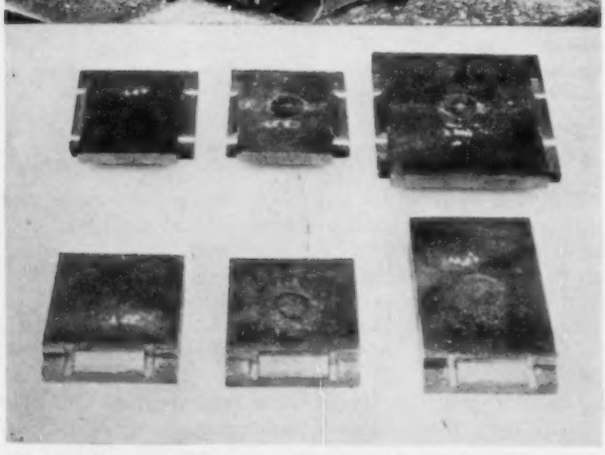


Fig. 15—Shear Test Specimens—Plug and Fillet Welds in Combination

Type of Welds	Direction of Loading with respect to Fillet Welds	Average Breaking Load. (lbs.)	Allowable Working Load for Joint @13600 p.s.i. (lbs.)	Factor of Safety for Joint.
FILLET WELDS	Longitudinal	44 870	9 600	4.67
	Transverse	45 420	9 600	4.73
FILLET AND PLUG WELDS IN COMBINATION.	Narrow specimens.			
	Longitudinal	68 810	16 600	4.14
	Transverse	71 100	"	4.29
	Wide specimens.			
	Longitudinal	68 900	16 600	4.15
	Transverse	67 500	"	4.06
			Average---	4.16

Fig. 16—Average Shearing Strength of Fillet and Plug Welds

in accordance with the details shown in Fig. 13 to produce four specimens for each arrangement of welds. All the plug welds were $^{13}/_{16}$ inch in diameter, and the fillet welds were made as $^{5}/_{16}$ x 2-inch welds and then machined to $^{1}/_{4}$ x $^{1}/_{4}$ x 2-inch fillet welds before the specimens were tested. Shaped milling cutters, as shown in Fig. 14, were used to trim the faces of the fillets, and end mill cuts were used to trim the welds to length. The test specimens were cut from the joints having multiple welds by saw cuts midway between the welds, and those prepared as separate joints were machined after welding.

TEST RESULTS FOR COMBINATION PLUG AND FILLET WELDS

Typical specimens of the joints tested are illustrated in Fig. 15. The average strength of the joints connected by both plug and fillet welds, calculated from the nominal area of their welds, was 56,380 psi, but this is probably not a true measure of the actual unit stresses because of the complexity of stress distribution in the joint. The effectiveness of plug and fillet welds in the same joint is best evaluated by comparing their strength with their allowable working load, as shown in Fig. 16. The average factor of safety shown by this comparison is 4.2, and the minimum for any weld was 3.8. Neither the orientation of the welds with respect to the applied load nor the spacing between the plug and fillet welds had any effect on the strength of these joints.

CONCLUSIONS

Plug welds in holes made by any of the common methods, punching, drilling, gas-cutting, or in countersunk holes, may be stressed in shear at the working stresses ordinarily allowed for fillet welds. The nominal diameter or size of the hole in which the weld is made should be used in all calculations of its working stresses or load-carrying capacity.

The results of these tests show that plug welds made in cylindrical holes having a diameter equal to the plate thickness plus $^{5}/_{16}$ inch have satisfactory penetration and fusion over the entire root area. Welds made in punched holes of this diameter are more economical of preparation

and welding than those made in larger holes or in holes made by other methods. Plug welds in plates up to $^5/_8$ inch thick should be made flush with the plate surface. Holes in thicker plates may be filled only one-half of their depth, if only strength and economy govern their design. Plug welds in plates over $^3/_4$ inch thick are not usually economical.

Countersinking of the holes for plug welds adds to the cost of preparation and welding of the joint, but it creates no advantage in weld strength or soundness. Welds in drilled or gas-cut holes are satisfactory in strength and soundness, but they are not economical because the joint preparation is expensive.

The test of slot welds shows that their characteristics are essentially the same as those of plug welds, and they are not affected by the orientation of the applied shearing stress. The nominal dimensions of the slot and the unit stresses ordinarily allowed for fillet welds are a suitable basis for the design of slot welds.

The test of plug and fillet welds in the same joint shows that they act together in sustaining the applied load and that they may be safely designed at the working stresses ordinarily allowed for fillet welds. The strength of such joints is not influenced by the relative spacing of the welds nor by the orientation of the test load with respect to the fillet welds.

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FLAME-TREATING*

By J. H. ZIMMERMAN†

INTRODUCTION

WHILE flame-hardening, as a process, needs no special introduction to the heat-treater, metallurgist or engineer, it is believed that certain recent developments which have not been publicized to any appreciable extent, and certain allied processes which have been developed as outgrowths of flame-hardening may be of interest. In this paper are described certain of the more recent applications of the flame-hardening process to special shapes requiring unusual control of contour of the hardened zone, and to special materials to which the process has been applied only recently with success. The general subject of flame-softening is discussed in some detail with particular respect to the important part played by this process in the oxyacetylene cutting of the hardenable steels. In addition, consideration is given to the relatively new idea of utilizing the oxyacetylene flame as a means for locally increasing the physical properties of highly stressed parts in regions of high stress concentration.

I—FLAME-HARDENING

General.—Flame-hardening as a heat-treating process has been defined as the surface-hardening of parts made of quench-hardenable material, accomplished by rapid heating of the regions to be hardened with the oxyacetylene flame, and by subsequent cooling by the application of a suitable quenching medium. The principles involved are in no way different from those which have been the underlying essentials of any process of hardening by heat-treatment. The distinguishing feature of the process has been the inherent flexibility which permits hardening of such surfaces of a part as may require high hardness, without the hardening of sections wherein such hardness is not required, or where it may, in fact, be undesirable.

The flame-hardening process occupies a unique position in the field of heat-treating It can be used as a substitute for full hardening and tempering or in conjunction with the same process. It frequently can be used as a substitute for, or an improvement on, other surface-hardening methods, such as case-hardening by carburizing or nitriding. In very rare cases only, however, does the process compete with hard-surfacing as accomplished by deposition of a wear-resistant material of widely different properties than the base metal.

Without going into detail regarding the competitive position of flame-hardening, it can be said that if surface hardness of certain regions only is desired, such hardness generally can be obtained by means of flame-hardening more quickly and more economically than by any other method. Where high core properties are desired, flame-hardening is not a substitute for full hardening, but must be used in conjunction therewith. Where high local surface hardness is required, flame-hardening frequently proves to be economical in comparison with other case-hardening methods. On the other hand, flame-hardening is not economical as applied to small parts which are usually carburized and hardened in bulk. Finally, as flame-hardening produces no changes in the composition of the metal hardened, it cannot serve as a substitute for the hard-surfacing processes which involve the deposition of special wear-resistant alloys.

In heating parts for surface-hardening by the flame-hardening process, the high heating value of the oxy-acetylene flame has made possible the great degree of flexibility of the process. Considerable variation in degree of hardness and case depth can be obtained through proper manipulation of the flames.

In quenching, it may be said very simply that the same principles of cooling that apply in other methods of heat-treatment apply in this instance. The faster the rate of cooling from above the critical temperature, the greater the degree of hardness. In certain instances it has been found possible to produce higher surface hardness in a given material by the flame-hardening method than can be obtained by any other method of heat-treating. This is because of the steep temperature gradients which may be obtained in heating the surface metal to a suitable hardening temperature, with the subsequent rapid flow of heat to the cold base metal beneath, in addition to the usual flow of heat to the externally applied quenching medium. Obviously, this extreme quenching action is not to be obtained on the surface layer of a part which has been heated to hardening temperature throughout.

In the course of locally hardening the surface regions of a part, the volume changes involved are of insufficient magnitude to do more than set up residual strains of a

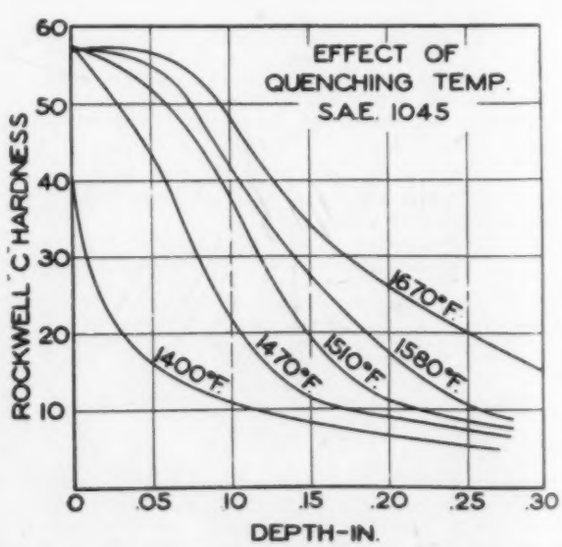

Fig. 1—Curves Showing the Relation Between Surface Temperature, as Measured by Means of an Optical Pyrometer, and Case Hardness Contour

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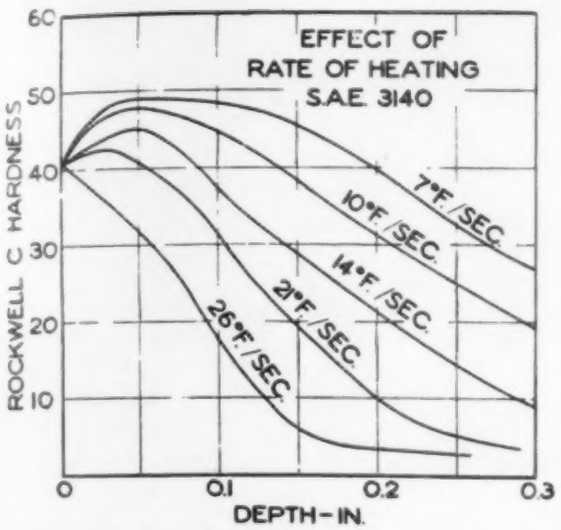


Fig. 2—Curves Showing the Relation Between Rate of Heating and Case Hardness Contour

minor order. These may be effectively eliminated or minimized by a tempering treatment at 350 to 400° F. This treatment must be recognized as a necessary part of the flame-hardening process, as is the case in all other quench-hardening processes. The tempering or drawing may easily be accomplished by means of an oil bath or oven.

The two principal features of importance in applying the flame-hardening process are the hardness and depth of the hardened zone. In general, the hardness obtained is quite closely allied with the rate of cooling, although it is obvious that if the attempt is made to secure too deep a case, some hardness must be sacrificed through diminution of the quenching action because of slower rates of cooling. The depth of case can be controlled within reasonable limits by the intensity of heat application prior to quenching.

These principles are illustrated as follows:

In Fig. 1, the relation between quenching temperature and depth of case is shown. It is obviously impossible to maintain a uniform temperature throughout the zone at the ideal temperature only slightly above the critical. However, it has been found that because of the heat of transformation, quite appreciable case depths may be obtained with attendant grain refinement.

As would be expected, the more rapid rates of heating produce the thinner cases, other factors being constant, as is illustrated in Fig. 2.

The following illustrations are intended to describe the several methods of flame-hardening, their effects upon a number of engineering materials, the type of apparatus and machinery employed, and, in a general way, the results that may be expected with proper application of the process.

Methods.—There are four general methods of producing surface hardness by means of the oxyacetylene flame. These are referred to as stationary, progressive, spinning and combination hardening. The latter method involves a combination of spinning and progressive motions.

In the stationary method both the work and the heating flames are stationary and contact is maintained for such time as may be necessary to heat the surface metal to the required temperature and depth. The heating is followed by suitable quenching. This method is illustrated by Fig. 3. In this application the ends of the valve stems to be hardened may be either slightly below or slightly above the surface of the quenching bath, depending upon the material and section.

The progressive method of hardening involves passage of the heating flames along the surface to be hardened, closely followed by passage of a suitable quenching jet or spray where necessary. In the case of self-hardening steels the quench may be omitted. Special heads employed in the progressive hardening of printing press clip ways are shown in Fig. 4. In this is illustrated the relationship between the flame and quench drillings. Attention is called to the excellent contour control obtained in this application.

The spinning process involves rotation of the work before a group or groups of heating flames so located as to produce the desired hardness contours with the subsequent application of quenching sprays or other cooling means. A crankshaft bearing spinning set-up is shown in Fig. 5. In this case the shaft is revolved between two heads which include both heating and quenching drillings.

The combination hardening method involves spinning of the work piece and progressive travel of the heating and quenching apparatus. This process is illustrated by the experimental roll-hardening machine shown in Fig. 6, in which a rotating roll is subjected to progressive application of heating flames and quench.

Materials.—While a wide range of materials may be successfully flame-hardened, by far the most popular material is the plain carbon steel of the S. A. E. 1045 type. This steel has been found to be responsive to surface-hardening to an extent sufficient for most applications. It is readily available and relatively inexpensive. It was at first suspected that the deep and shallow hardening steels, so-called because of their response to hardening by other methods, might respond differently to the flame-hardening process. As a check, two S. A. E. 1045 steels of close chemical compositions but of A. S. T. M. grain size 2–4 and 6–8, respectively, with corresponding deep and shallow hardening characteristics, were investigated and found to react to the process in an identical manner.

Improved core properties, compared with those obtained by preheating the plain carbon steels, may be obtained by the usual recourse to alloy steels. Steels of the S. A. E., 3100, 4100 and 6100 types have been pretreated to give exceptionally good core properties and subsequent local flame-hardening has produced the req-

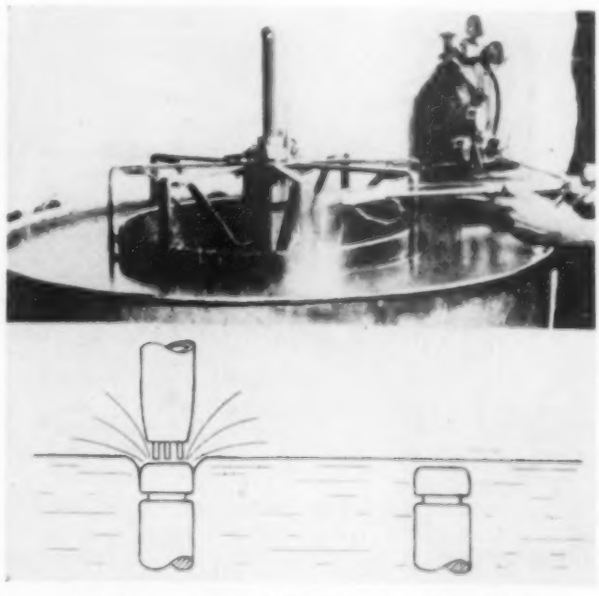


Fig. 3—"Spot" Flame-Hardening of Valve Stem Ends

uisite surface hardness in excess of the core hardness. The expected interior zone of low hardness in pretreated steels is present in most cases but to an almost negligible extent. By this is meant that in passing from the high surface hardness to the normal core hardness of the pretreated alloy steel, the zone which has been tempered to a higher temperature than that to which the entire part was subjected in pretreating has not been appreciably softened by the flame-hardening. The time element and the sluggishness of reaction of the alloy steels are probably responsible for this helpful condition. Very little difference is to be observed in the microstructure of flame-hardened alloy steels as compared with the structure of plain carbon steels of equivalent hardenability.

Early in the introduction of the graphitic steels, experimental work was conducted to determine the practicability of applying the flame-hardening process to this material. Unusually coarse martensitic structures have been obtained in the flame-hardening of such steels, but the coarsening has not been found to be disadvantageous in the service performance of flame-hardened graphitic steel parts.

In the flame-hardening of the cast ferrous materials, no difficulties have been encountered in the hardening of

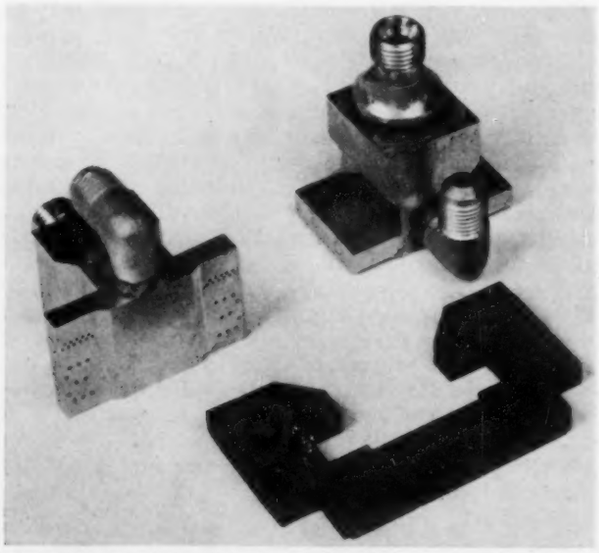


Fig. 4—Special "Progressive" Type Flame-Hardening Heads for the Treatment of Printing Press Clip Ways with a Macroetched Section of a Hardened Way. Note the Excellence of Contour Control at the Four Hardened Surfaces

steel castings in numerous applications. It should be understood in this instance, of course, that flame-hardening will not produce high surface hardness on a decarburized surface. Flame-hardening on machined castings where such irregular surface conditions have been removed, has resulted in uniformly acceptable hardnesses.

In the hardening of gray cast iron, difficulty may be encountered where the combined carbon content does not fall within the range of 0.50 to 0.80 per cent. Irons containing less than 0.50 per cent combined carbon will not develop maximum hardness, while those having combined carbon in excess of 0.80 per cent are liable to crack. Usually, any iron which falls within the A. S. T. M. classifications of 35 to 50, inclusive, can be flame-hardened satisfactorily.

Misleading results have been reported in the hardening of cast irons because of the difficulty experienced in accurately measuring the surface hardness. Irregular impressions are obtained in penetration-hardness tests of flame-hardened cast iron because of local shattering.

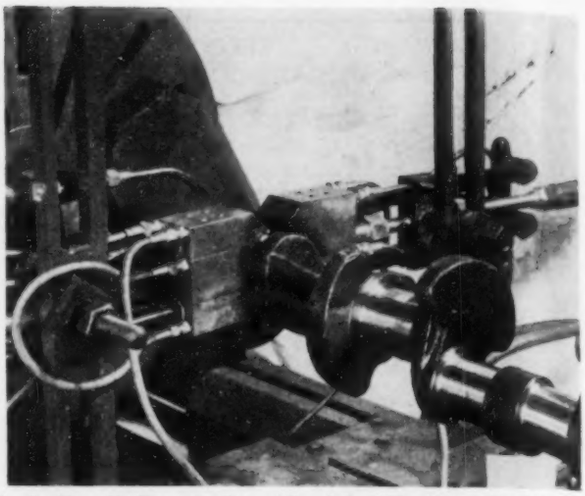


Fig. 5—Close-Up View of a Pair of Crankshaft Hardening Heads in Position for Hardening by the Spinning Method

Irregularities in test results, traced to this difficulty, have been eliminated by check tests using the scleroscope with great care.

In the flame-hardening of malleable cast iron, satisfactory results have been obtained. Most commercial applications have involved the hardening of castings on "as-cast" surfaces. In such instances, full case properties have been developed slightly below the surface because of the thin skin of pure iron characteristic of black heart malleable castings. This thin layer of soft material has not been considered objectionable because, after only a relatively small amount of wear, the hard flame-hardened metal presents itself, and the resistance to further wear is correspondingly increased. If maximum hardness is desired at the surface of a malleable part, it is necessary to machine off the carbon-free layer. Investigations to date indicate, however, that, whereas malleable castings have been successfully flame-hardened, this material is not to be recommended except where extremely close control of the process can be maintained.

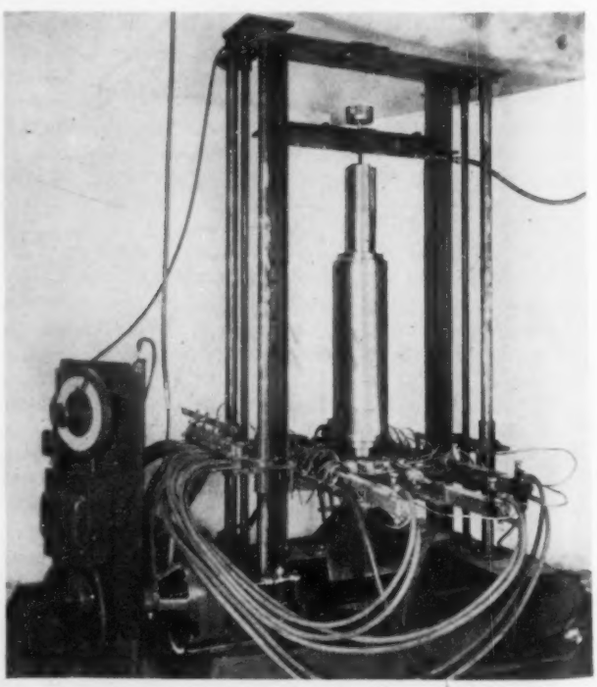


Fig. 6—Experimental Roll Hardening Machine with 10 In. Diameter Knurled Roll in Position for Hardening by the "Combination" Method

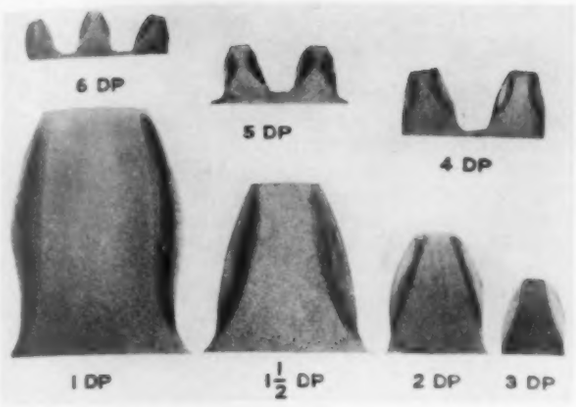


Fig. 7—Typical Sections of Flame-Hardened Gear Teeth from 1 to 6 Diametral Pitch

Excellent results have been obtained with the special types of cast materials which do not fall into the recognized classifications other than the somewhat vague group of materials which might properly be termed "semi-steels."

Apparatus.—Various papers on the subject which have appeared in the literature during the past year or so have illustrated the types of apparatus employed in the flame-hardening process. From the apparatus manufacturer's view-point the equipment divides itself into two groups, the first of which includes the parts which are used to a sufficient extent to warrant manufacture in quantity, and which are therefore considered as stock items; the second group comprising the special equipment which is developed to produce the necessary results in specific applications.

Early in the development of the process, it became apparent that gears in the sizes ranging from 1 to 3 D. P. would lend themselves admirably to the process. It was not long, therefore, before so-called "standard" or "stock" flame-hardening heads for gears in this group were available.

In examining heads specifically designed to harden gears with the requisite contour it will be noted that the flame spacing is closer toward the root of the tooth and that the quench drillings follow very closely after the flames. The proper spacing of the flame has been developed after considerable experimental work in order to compensate adequately for the variation in mass effect between the top of the tooth and the root.

A somewhat different type of stock apparatus is available in the form of removable tips of various lengths which may be inserted into standard multi-flame heads for various numbers of flames. By blanking out certain positions in such heads and employing insert tips of various lengths, considerable flexibility of standardized equipment can be obtained in handling the hardening of parts of a wide variety of shapes and dimensions. Insert tips in standard multi-flame heads have, for example, been used in successfully producing the required contour and hardness in the hardening of pipe wrench jaws. It should be understood in this application that the wrench jaws are assembled side by side and treated by a continuous progressive hardening. Obviously, compensation must be made for a mass effect, and the heat input is therefore varied by blanking out tips to provide for the desired contour.

There is practically no limit to the types of special heads which may be developed to meet specific needs. As an example of this, there may be mentioned custom-built drilled-face crankshaft hardening heads with integral quench. Unfortunately, heads of this type are limited to a relatively small range of dimensions in the hardening of crankshaft bearings, providing the required hardness contours are exacting. In these heads the heating flames are spaced to provide for variations in mass effect.

A somewhat different type of special flame-hardening head may be made up as an assembly of small standard heads, special clamps and auxiliary quench as employed in the hardening of rolls by the combination method.

Machines.—In addition to the gas-handling apparatus essential in the process, various types of machines are also required as motivating units. Here, again, types of equipment vary with the nature of the work.

The portable cutting machine has been used for progressive flame-hardening since the beginning. Many other machine types have been employed with success, the only requirements being that the machine must be capable of acting as a steady support for the heating and quenching equipment and capable of moving the hardening apparatus along the work surface at a proper speed, and at a proper distance from the surface to be hardened.

In using the spinning method many types of lathes have been quickly and cheaply converted to suitable flame-hardening machines, as shown in Fig. 5. Where the work is quenched while spinning, heating heads with integral quench such as illustrated in Fig. 5 or heating heads with an auxiliary quench may be used. It is also possible to quickly quench the heated work in a suitable bath by means of a quick-releasing chuck. The latter practice is recommended for the spinning process when the composition of the material requires an oil quench in order to obtain the desired case.

The combination hardening method employing both spinning and progressive motions has found a wide application in the flame-hardening of rolls, shafts and liners. A special flame-hardening machine employed in the hardening of shafts or rolls is shown in Fig. 6. In either case

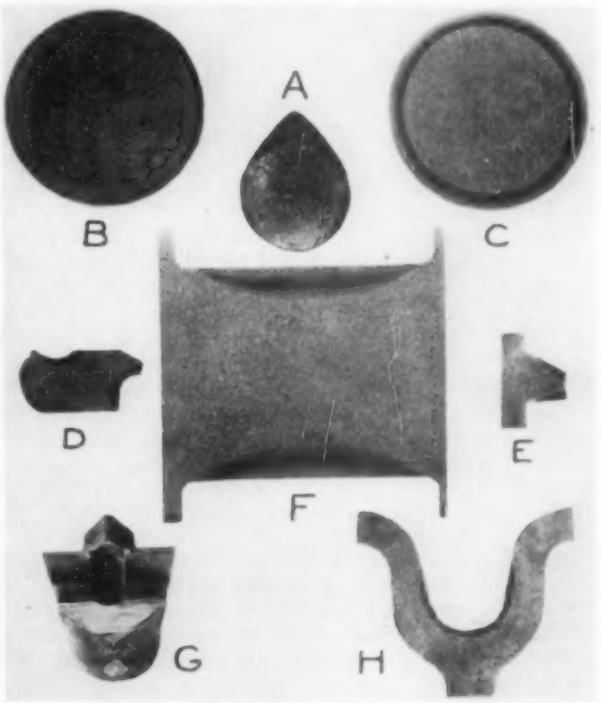


Fig. 8—Macroetches of Representative Flame-Hardened Parts

(A) Cast-iron Cam, (B) Shaft with Light Case, (C) Shaft with Deep Case, (D) Section Through Flame-Hardened Caster Race, (E) Pressure Screw Thread, (F) Longitudinal Section of Flame-Hardened Crankshaft Bearing, (G) Partially Sectioned Detachable Drill Bit, and (H) Sectioned Cast-Iron Sheave Wheel

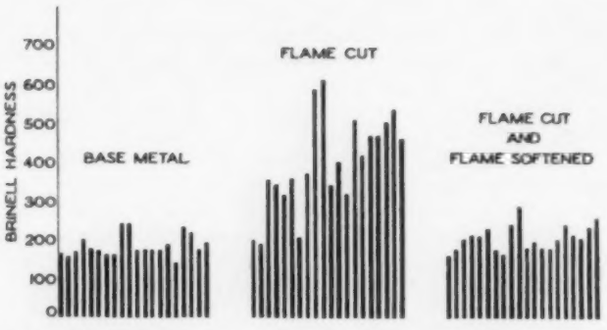


Fig. 9—Brinell Hardness at the Cut Surface of a Group of Representative High Tensile and Low Alloy Steels—as Received, as Flame-Cut and as Flame-Cut and Flame-Softened

the work piece is revolved and the heating flames and quenches progress from one end of the hardened area to the other.

A somewhat similar machine has been designed for the hardening of the interior of cylindrical pump liners. In this machine, as in the previous case, the liner is rotated as the internal hardening head and quench head are traversed longitudinally.

Results.—The foregoing illustrations have been used to illustrate the fundamental methods and equipment employed in flame-hardening.

With more specific respect to the results to be obtained by the proper application of these methods, a number of macroetches have been included. In Fig. 7 is shown a group of etched flame-hardened gear teeth ranging from 1 to 6 D. P. Unfortunately, the teeth shown represent a number of steels and considerable variation in etching and photographic technique. However, the typical contour of the hardened region is well illustrated.

Figure 8-A is a macroetch of a flame-hardened cam which shows concentration of the hardness at the surface subjected to the highest contact loads.

In Figs. 8-B and 8-C are shown macroetches of two rounds which have been hardened by the combination method. Attention is called to the uniformity of case in each example and to the range of controlled case depth.

Previous reference has been made to the flame-hardening of crankshaft bearings by the spinning method. The result obtained by the crankshaft set-up shown in Fig. 5 is illustrated in the longitudinal etch of a hardened shaft, Fig. 8-F.

Other interesting illustrations of the economical placement of hardened metal are shown in the sectioned caster race, Fig. 8-D, the pressure screw thread, Fig. 8-C, the partially sectioned detachable rock drill bit shown in Fig. 8-G, and the sectioned flame-hardened sheave wheel, Fig. 8-H. The flame-hardened sheave wheel shown illustrates perfectly the extreme flexibility of the flame-hardening process with respect to the confinement of the hardened material in the regions where hardness is essential.

FLAME-SOFTENING

General.—Diametrically opposed to the basic demands for the flame-hardening processes are the needs which have led to the development of a somewhat newer procedure known as "flame-softening." Where the objective in the first process is to increase surface hardness, the purpose in the second is to soften material which has been, or might otherwise become, hardened. The numerous industrial applications of flame-softening include: the local annealing of carburized or cyanided case-hardened parts to permit drilling, tapping or machining; the same with respect to fully hardened parts; the local softening and refining of finishing weld passes; the annealing of sheared edges and other work-hardened parts; the softening of flame cut riser pads, etc. Another application of flame-softening is in connection with the flame-cutting of the air-hardening steels, with particular reference to steels of the alloy and high tensile structural types. These, when flame-cut by the usual methods, may harden sufficiently to leave cut edges which are lacking in toughness, ductility and, in some instances, machinability.

The fundamental action of flame-softening when used in conjunction with flame-cutting is in supplying such preheat, postheat or both, as may be necessary to leave the cut edge in an acceptably softened and ductile condition. There are three methods of using flame-softening heads for the removal of hardness from cut surfaces. As the first example, a single heating head may be applied to the top of a plate which is being flame-cut. The heat is applied simultaneously with and immediately before or after the cut has been made. The effect is either to slow the rate of cooling to a sufficient extent to prevent undue hardening, or to temper the partially hardened cut surface.

A second process employing the simultaneous application of heat from both the top and bottom of the plate may be used. This procedure is more desirable when the thickness is such as to make heating from one side only uneconomical or destructive to the top surface because of the longer soaking time required. The second set-up is restricted to cuts where a relatively thin width of scrap is removed. The third method of flame-softening involves the application of the softening flames directly to the cut surface immediately after the cut has been completed.

By employing one of the foregoing flame-softening processes it is possible to flame-cut materials which otherwise would require expensive machining. Use of the process also eliminates the need for chipping or grinding away the thin hardened surface which is left on the hardenable steels when the ordinary methods of flame-cutting are employed.

While the results obtained by the use of the flame-softening process in connection with flame-cutting may be generally duplicated by furnace-treatment of the plates as a whole, either by preheating before cutting or by heat-treating after cutting, appreciable savings can be realized by the use of the flame-hardening process instead of the more cumbersome and less economical methods of furnace-treating.

Principles.—The underlying principles of the flame-softening process are predicated upon the accepted metallurgical bases of other well-known heat-treatments. The gradients set up by ordinary flame cutting may be quite steep, and it is reasonable to expect, under such conditions, that a thin layer of the surface material will be subjected to a fairly rapid rate of cooling because of radiation to the surrounding air and conduction to the cold base metal. The softening of these gradients may be accomplished by the use of the preheating treatment and, as is well known, with the corresponding reduction in rate of cooling, the subsequent hardening is negligible.

With further respect to the simultaneous application of heat with cutting, it is also possible to employ postheating effectively. This treatment may consist of a tempering of the previously hardened metal by reheating to a temperature slightly below the critical, or it may involve reheating the surface metal to an annealing temperature slightly above the critical. With the broad temperature gradient set up and the deep volume of heated material,

the rate of cooling is such as to leave the material in a relatively soft, ductile condition.

In considering the third method of flame-softening it is assumed that prior to the application of the treatment the work has been flame-cut and cooled to a temperature below the critical. Generally speaking, the sooner thereafter that the softening treatment can be applied, the better, since the more delicate steels will sometimes crack if cooling is allowed to progress to shop temperature, particularly in cold weather. By applying heat directly to the face of the cut, a straight tempering treatment may be accomplished, or, if a more thoroughgoing treatment is desired, a complete treatment may be applied consisting of heating the cut surface to slightly above the critical, thus refining the previously coarsened material, following with either a tempering to a high tempering temperature or a cooling, reduced in rate by the application of a second bank of heating flames.

Results.—The results obtained in applying flame-softening are illustrated graphically in Fig. 9. Some steels normally respond to the ordinary flame-cutting process by hardening at the cut surfaces to from 200 to 500 Bhn. However, when properly treated by either preheat or postheat in conjunction with cutting, these steels respond to the combined cutting and treating by hardening to an acceptable degree, usually to within the range of 150 to 300 Bhn. The general effect* of the treatment on a representative group of steels as clearly shown in Fig. 9.

A striking example of the utility of the flame-softening process is in the softening of flame-cut armor plate. In this application, appreciable savings and notable increases in production have been realized through the substitution of flame heat-treatment for full furnace-treatment.

FLAME-STRENGTHENING

General.—Of the three flame-treating processes described in this paper, the third, flame-strengthening, is the newest and least known. It is, however, self-defining by name. In application it is practically identical with the flame-hardening treatment. The purpose of flame-strengthening differs appreciably from that of the above-mentioned processes, however, in that the intent is to strengthen highly stressed parts locally in the regions of excessive concentration of stress. An example of such stress concentration, as determined photoelastically, is shown in Fig. 10.

The process is directed particularly at parts which are to be subjected to repeated stresses and which are thus subject to failure by fatigue. In protecting against fatigue failures it is again—to borrow the slogan of a well-known paint manufacturer—a case of "Save the surface and you save it all." In other words, while the treatment may appear to be identical with flame-hardening, it may be applied to sections of a part, which will never be subjected to wear, for the specific purpose of increasing mechanical strength as resistance against the formation and propagation of fatigue cracks. By virtue of the extreme flexibility of the process, the use of flame-strengthening makes it possible to effect savings in comparison with the complete heat-treatments where, in many instances 100 per cent of a part would be fully hardened and drawn in order to increase the strength of the 1 per cent which may be subjected to the maximum stresses.

Fig. 10—Photoelastic Study Showing Stress Concentration at Shallow Grooves in Pure Bending

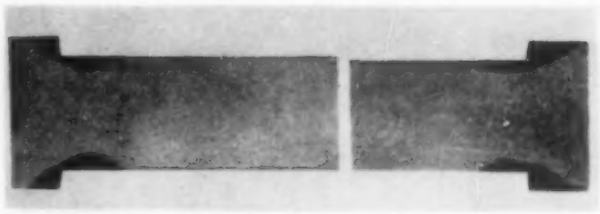


Fig. 11—Macroetch of Failed Fatigue Test Specimen Showing Flame-Strengthening at the Regions of Stress Concentration

Methods.—As previously stated, there is practically no difference between the flame-strengthening procedure and that for flame-hardening. In order to produce the desired contours of strengthened metal and in order to control the fade-out of this strengthened section into the base metal in regions of lower stress, and thus prevent sharp discontinuities, it has been found desirable to employ special heating heads where the complexity of the part does not lend itself readily to the use of simple or standard equipment.

The cooling in the flame-strengthening process may be somewhat less drastic than in the case of flame-hardening. Whereas it is generally agreed that high hardness is indicative of great strength, unfortunately the strength so indicated is not, in turn, indicative of the maximum fatigue or endurance properties. Somewhat lower than maximum hardnesses have been shown to be advantageous with regard to resistance to repeated stresses. This is probably caused by the need for a certain amount of ductility to provide for minute plastic deformations in regions of high stress concentration. The need for tempering, even though at a low temperature, is still more obvious in the case of flame-strengthening than in the case of flame-hardening.

Results.—While no specific information concerning the performance of flame-strengthened parts in service is as yet available, the results of laboratory tests are of interest. In Fig. 11 is shown part of a sectioned and etched fatigue specimen of the type employed in a series of tests to determine the advantages of the flame-strengthening process. In this specimen a sharp shoulder was intentionally introduced in the mid-section of the test specimen which is submitted to uniform bending during rotation. As is well known, and as has been previously indicated by the photoelastic illustration in Fig. 10, this abrupt change in section is a stress raiser of appreciable magnitude. It was thought that if flame-strengthening could divert the fatigue failure from the sharp cornered fillet to the shank of uniform diameter, the treatment, in effect, would have completely eliminated the weakening effect of the stress raiser. This has been found to be the case, as is shown by Fig. 11 which is a longitudinal section of a fractured specimen showing the break at the center

In order to investigate further the effect of flame-

* For more specific information see "Structural Steels Flame Softened During Gas Cutting," by H. H. Moss, *Iron Age*, Dec. 30, 1937, and Jan. 20, 1938.

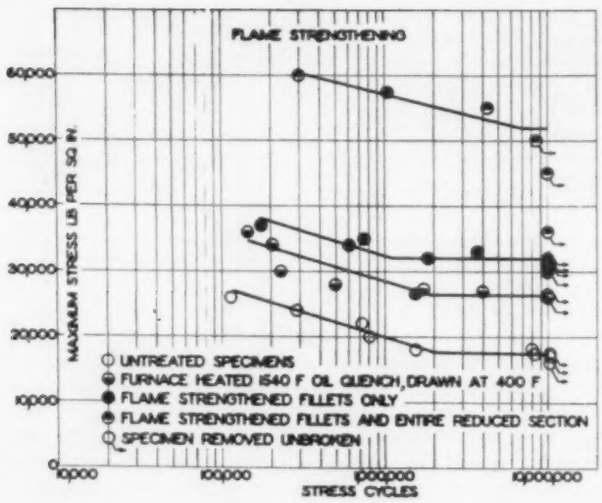


Fig. 12—Graphical Representation of Fatigue Test Results Showing Determination of Endurance Limits

strengthening, the entire reduced section surface, as well as the fillets, was strengthened in a second series of specimens. In these tests it was soon found possible to throw the fatigue failures to the untreated metal in the sections of large diameter. Actual dimensions of the specimens under test were $^{7}/_{16}$ in. and $^{1}/_{2}$ in. for the small and large diameters, respectively. This variation in diameter corresponds to a much greater difference in the induced stress under load, the ratio of stresses for a uniform bending moment being almost 1.5:1.

The results of one series of comparative fatigue tests are shown in Fig. 12. The endurance limits for four sets of specimens of the same type but of different treatment are shown. The base material in this series of tests was S. A. E. 1045 steel. No attempt was made to determine the actual endurance limit of the material, which is probably in the neighborhood of 45,000 lb. per sq. in. Instead, the calculated stresses for the test specimens were based on the small diameter without regard to the stress-raising factor corresponding to the sharp-cornered shoulder.

In the lower curve it will be seen that the nominal endurance limit of the test specimen, untreated, was in the neighborhood of 18,000 lb. per sq. in. If it is assumed that the test material itself has an endurance limit of 45,000 lb. per sq. in., the actual stress-raising factor indicated is 2.5, a value which is not inconsistent with published data.*

In the second curve from the bottom, the nominal endurance limit is indicated to be approximately 26,000 lb. per sq. in. This series of specimens was oil-quenched from 1540° F. and drawn at 400° F.

The next curve showing a nominal endurance limit of 32,000 lb. per sq. in. corresponds to the series of specimens treated as indicated in Fig. 11, namely, untreated base metal with flame-strengthened fillets. It is interesting to note that this relatively sparse heat-treatment has developed improved fatigue resistance as compared with a fully quenched and drawn specimen, although it must be admitted that the fully hardened specimens would probably have shown improved results had they been water-quenched.

The upper curve, indicating a nominal fatigue limit around 52,000 lb. per sq. in. was obtained in testing a series of specimens which had been flame-strengthened not only at the fillets but across the entire reduced section. The improvement is obvious.

The results of these and other laboratory tests in progress indicate that there may be considerable future for the flame-strengthening process.

CONCLUSION

In conclusion, it may be said that, first, while flame-hardening, as a process, is no longer new, applications continue to become more numerous and it is believed that flame-hardening, as a method of heat-treating has definitely established itself as being both economical and practicable in many industries. Secondly, although less well known, the flame-softening process has now been given sufficient commercial application to indicate that it, too, has a definite place in the field of heat-treatment. And finally, flame-strengthening, the latest of the flame heat-treatments, gives every indication of still another important field of use for the oxyacetylene flame as an industrial tool.

* See "Photoelastic Studies in Stress Concentration," M. M. Frocht, *Mechanical Engineering*, 58, 485 (1936).

HIGH SPOTS IN SHIP WELDING*

By E. D. DEBES†

VARIETY OF WORK

THE term "High Spots" in the title of this paper refers to problems which we have with us at all times but as an introduction I would like to explain why we have such spots in shipyards. I do not believe that it is generally understood that a large shipyard like our "Fore River Plant" carries out almost any type of welding of a great variety of metals which reminds me of a remark made by a friend of mine who was giving a lecture before the Boston Branch of the AMERICAN WELDING SOCIETY. During his talk he was discussing the problems and troubles (High Spots) at his plant and made the remark that "Debes" down there has no problems because he only welds ships.

We cover almost all types of welding except high pressure vessels, these are sublet to concerns which specialize in that branch of the welding industry.

* Presented at Annual Meeting, A. W. S., Chicago, Oct. 23 to 27, 1939.
† Bethlehem Steel Company, Shipbuilding Division, Quincy, Mass.

For a 35,000 ton battleship such as the "MASSACHUSETTS" now building at "Fore River," we are constructing welded Gun Turret units weighing 250 tons apiece and consisting of material from $^1/_2$ to 5 inches thick, stern posts weighing 70 tons and 40 ton rudders and then all down the line to welding of C. R. Steel 20 thousandths of an inch thick.

About 1,500,000 lb. of welding electrodes will be used on this vessel, which is to be about 70% welded, in order to lay down 4,500,000 linear feet of welding.

I referred above to "Rudders" and I may add that the largest rudder built at "Fore River" was for the "Airplane Carrier" "LEXINGTON." This rudder weighed 129 tons and was $12^1/_2$ feet thick (not $12^1/_2$ inches).

DESIGN

This is, of course, one of the greatest "High Spots" in ship welding as the welding cannot be successfully carried out unless the work in the drafting rooms is done with a full understanding of the facilities in the plant and the conditions under which work has to be done. Great progress has been accomplished in our plant along this line due to close cooperation between the technical staff and the production personnel and the experience gained since welding starting as an interesting experiment, so to speak, until now it is one of the most important departments in the plant. An example of what has happened may be of interest.

Some eight years ago we built our first all welded rudder and thought we had done a very fine job of designing. In building this rudder we had endless troubles, due primarily to distortion, but also to difficulty in forming material to designed shapes and inaccessible welds, in fact our Manager made the remark that he believed that "The d— thing took the country off the Gold Standard." Well, we got our heads together (or ducks in a row, as the saying is now) and radically redesigned the next rudder and set up a whole new procedure of welding, which by the way was the start of our present method of control of welding procedure about which more later. The results were very satisfactory and we have since built 16 rudders, some very large, following the same general design and procedure so that is now only another job and the "High Spot" has been smoothed out.

MATERIAL CONTROL

Due to the great increase in types of metals to be fabricated and welded, it was found necessary about 4 years ago to employ a metallurgist with the title of "Materials Engineer." All materials orders pass through his hands and I do not believe we could get along without such control as the number of points raised in regard to specifications and types of material is very great. A short time ago I was asked as to what kind of steel was used for a certain job about 25 years ago. I answered that we did not have a metallurgist at the plant at that time and did not give a damn. This, of course, is stressing the point, but at that time you could almost remember the characteristics of the comparatively few kinds of metals used in shipbuilding.

EQUIPMENT

We use mostly Constant Potential Machines, some 1000 amp. and some 1500 amp., all D.C. current, reversed polarity, and have outlets for 315 welders on one shift. We also have 30 single operator machines used for backing up the C. P. machines and in cases where straight polarity has to be used and where high amp. is used, as in our Machine Shop. Practically all our welders use helmets. Handshields are used in tight places and on some special work only. I understand that in England helmets are considered dangerous especially for men working on staging, which is the direct opposite of our experience. We use our own make of electrode holders. These are of the screw type and are completely insulated so that when there is no electrode in the holder it is dead. We have had some bad experience with the tong type, which cannot very well be insulated, due to holders being dragged over pipes and electric cables on board ship and burning holes in pipes and the metal coating of the cables. We are using a number of positioning tables mostly of our own make to suit special jobs. There is a great demand in the plant for more welding space and heavier Crane equipment in order to increase sub-assembly welding and that is one of our greatest "High Spots" and is being given proper consideration.

PRODUCTION CONTROL

All our welding is carefully controlled:
First—by close cooperation with the drafting rooms
Second—by general procedure write-ups
Third—by detail sequence procedure schedules.

These sequences cover every step in ship and shop welding and are developed in the Mold Loft in close contact with the Welding Engineer, Foreman, Superintendents and the General Production Department.

PERSONNEL CONTROL

Our direct control of personnel is by the Foreman of the Welding Department through his Assistant Foreman, Quartermen, Leading Men and Inspectors. The inspectors are the department's men whose duty it is to inspect work which is reported ready for welding. Welding is not started until conditions are satisfactory to the inspectors. A considerable decrease in cost of both welding and shipfitting has been obtained since this inspection was put into effect. It used to be the opinion that "this is a welded job and we do not have to be fussy," while if anything better fitting is required for welded work than for riveted construction. The saving in shipfitting is due to the fact that much less refitting is done as more care is now taken to pass inspection. Under personnel control may also be mentioned working conditions such as staging and ventilation. We have to take great care to provide proper ventilation for men working in the numerous small compartments on the ships. This is accomplished by large ventilating sets with branches to the compartments and with small units which may be brought to the job. The men are also provided with respirators and when working in "heated houses" on large weldments where preheating is required, cooling rooms are provided and lemon and salt tablets given to the men. The supervisors also inspect staging to insure that working conditions are satisfactory. There are at present 650 men all told in the Welding Department. Welders are generally obtained by training men in our Welding School. We are very pleased with the fact that about 300 unskilled men have learned the welding trade in the school and are now working in the plant. Very few of these men have left the plant.

Ninety-five per cent of the welding is on the Bonus Piece Work System to the satisfaction of the management and employees.

GENERAL NOTES

One special job was the welding of the deck of a large vessel consisting of a heavy framework covered with 4 lb. ($^3/_{32}$ inch) galvanized plating. To avoid buckling of the plating mechanically straightened plates were ordered and the welding procedure carefully worked out as results of extensive experiments and test. No straightening has been done on this deck after welding as the small amount of buckling is taken care of by the heavy wood planking bolted on top by means of welded studs and nuts. It is understood that as much as $35,000 has been spent in straightening on similar jobs. The main features of the welding were to tack all plates in place with light flat bar stiffeners welded on the underside. The seams and butts were then welded, plate by plate, using a wandering sequence. This procedure had the effect of drum-heading the plate.

With our improved types of holder and stub control (the men turn in their stubs for new wires), we have increased our deposit rate from 52 to 65%, and as we buy some $56,000 of electrodes per year, this means a saving of $7500.

FUNDAMENTALS OF RESISTANCE Welding*

By S. M. HUMPHREY†

THE resistance welding industry and the use of resistance welding in general during the last thirty years have passed through a period where the development of the process and the equipment was more or less empirically to the point where it has become an extremely useful and widely used production tool.

It is unfortunate, however, that due to the empirical development there is very little recorded engineering information available regarding either the process or the equipment, and, furthermore, there is very little true scientific knowledge recorded. It is believed that the development has now reached the stage where further progress will depend to a large degree upon the amount of industrial and pure research work that is done in the field. Resistance welding has already been applied to the more simple mild steel structures and its greatest future field in the way of new applications lies in its use in alloy steels and light metals such as duralumin.

In order that the technique of resistance welding may advance along more scientific lines than it has in the past, it is of vital importance that everyone connected with it thoroughly understand the underlying fundamentals in order that they may intelligently apply information obtained by other workers in the field and in order that they in turn may intelligently record work which they do themselves so that it may become useful to others.

In recording of engineering data, a uniform language, so to speak, covering the various variables involved is very essential. The lack of such a language and the unsound scientific basis of some of the terms which have been used in the past have been perhaps the greatest single factor which has prevented the accumulation of accurate and proper engineering data.

For example, it is quite common to find a specification stating that it takes so much kva. to make a certain weld. To show how much in error and how useless such a statement is, let us analyze what happens electrically in making a weld and through what mental process the machine designer goes in order to design suitable equipment.

In its simple form, a resistance weld consists merely of overlapping two sheets of metal, placing them between two electrodes of high conductivity material under a certain pressure and passing through the sheets a definite current. In its simplest form, a statement of the type of material, shape and diameter of the electrodes used, the pressure applied upon the electrodes, the rms. value of the current passed through the stock, and the time interval during which the current flows, is a complete statement of the manner in which the weld is made. It is important to note that no mention has been made of kva. Only the current has been recorded and only the current affects the weld.

Suppose we have determined experimentally what this required current is. We are now faced with the concrete problem of designing a welding machine to weld a certain structure in which the weld consists of the same material and same gage covered by our above laboratory data. We start off with a definite knowledge that so much current is required. We now also know that our structure is of a certain shape and this determines the geometry of the welding machine which will reach into the structure and allow applying the electrodes at the proper point under pressure. Having thus determined the geometry of the welding machine, we can then determine the voltage required to cause the necessary current to flow through the welding machine arms. This voltage multiplied by the current results in a figure which is the kva. demand during weld.

This must not be confused with the kva. rating of the transformer which is determined in the following manner. As pointed out above, one of the parameters recorded in our original data was the time during which the weld current flowed; this time combined with the number of spots made in any one minute will result in knowledge of the percentage of total time during which the current is flowing, which is generally referred to as the duty cycle. From the operating duty cycle and the demand during weld we may readily calculate the kva. demand on 50% duty cycle which would result in the same heating of the welding machine.

If the welding transformer was rated at this kva., it

* Paper presented at Annual Meeting, A. W. S., Chicago, Oct. 22 to 29, 1939.
† Chief Electrical Engineer, The Taylor Winfield Corporation.

would from this point of view be sufficiently large to satisfactorily perform the work expected of it. There are, however, certain practical considerations from a design angle which enter in. For example—a very heavy current and a very low duty cycle might result in an equivalent 50% duty cycle kva. which was so low that if the transformer were built at this rating the impedance would be so high that sufficient current could not be obtained. From the practical point of view, either the equivalent 50% duty kva. or a kva. equal to one-quarter of the maximum demand, whichever is smaller, would be a satisfactory rating.

It is now important that the point be emphasized that the kva. of the transformer and the kva. demand during weld are very definitely functions of the geometry of the part to be welded and the machine itself and are in no way directly connected to the simple fundamental problem of spot welding two sheets of steel of known analysis and known gage. Bearing this in mind, it can readily be seen how useless such a statement that to weld two pieces of 12 gage steel required 50 kva.

The actual rating on the transformer has only one meaning and that is that the transformer will carry the kva. specified on the name plate on a 50% duty cycle without exceeding excessive temperature rise for the type of insulation used. The rating has no fundamental significance whatever regarding the ability of the machine to make a single weld.

If the above brief analysis will serve to start the industry thinking, from the electrical point of view, in terms of the fundamental quantity current, and to use the term kva. properly with due consideration of machine geometry and duty cycle, the time in preparing this article by the author will be considered well worth while.

The general outline of the above electrical analysis can be directly applied to all forms of resistance welding machines such as spot welders, projection welders, seam welders, etc., but in the case of the flash welder, there is one other factor involved, the flash weld is primarily an arc. In the arc welding field a great deal of work has been done from the pure research angle to gain accurate scientific knowledge of its characteristics and behavior and it is believed that this knowledge, if properly applied, can result in a better knowledge and subsequently an improvement in the use of the flash welding machine process.

From the point of view of power, the term kva. has again been abused as applied to these machines. As a matter of actual fact, during the flashing the area of the work and rate of burn-off are the determining factors of the current.

As the two parts to be welded are moved toward one another, the arc between them burns away the two pieces. As the speed at which two pieces are moved toward each other is increased, the arc gap shortens and the parts must burn away faster, otherwise they will come together and the arc will be snuffed out. Approaching a final limit determined by the impedance of the circuit the current automatically increases, giving the increased rate of burn-off necessary to prevent the parts coming together. It is important to note here that the current in the weld has been changed not by changing the transformer tap (or the loop), but merely by increasing the speed of the parts toward one another. It has been found experimentally that current densities in the arc seldom run any higher than 25,000 amperes per square inch. It has also been found that a voltage in the vicinity of 9 volts is essential for stable operation. If a voltage appreciably lower or higher than this is used there is a tendency for an unstable arc.

The main point it is important to note here is the fact that from the electrical point of view during the flashing period the fundamental parameter is the current expressed in terms of amperes or amperes per square inch. It must be the current which exists during the flashing period. The current which occurs at the start of weld before the arc has been established and the current that may exist at the end of the weld after the arc has been snuffed out by the upset motion, will be many times as high as the flashing period current. It is also of value to know approximately what these currents are. From a point of view of transformer rating, the same general considerations of part and machine geometry and duty cycle must be taken into account with the additional limitation that the voltage should be proper for a stable arc.

So far the discussion has been limited to electrical considerations. Mechanical considerations are equally important. It has, unfortunately, become the general practice to state that so much pressure is required to make a given weld. Unfortunately, this is not enough, hence much of our data on work done in the past is not complete. During a weld the moving electrode is actually in motion, hence the problem is one of dynamics and not of statics. For example, all other things being equal, such as size of electrodes, welding current, time of current and static pressure applied to the work before turning on the current but in one case the mass of the moving system is much greater than in the other case, the same welding results will not be obtained. Furthermore, even if the masses are identical but there is an appreciable difference in the friction of the two moving systems, again the weld results will be different.

The main point to be observed here is that in specifying the manner in which a weld should be made it is important that not only the static pressure at the start of the weld be recorded, but that the weight of the head and, if possible, some idea of the amount of friction involved should also be recorded.

All of the above factors should also be taken into consideration in specifying equipment for making resistance welds. If the engineers employed by our industrial plants today who have charge of resistance welding could all work along the line of exchanging information on the basis of the above terms and of specifying the manner in which welds should be made in those same terms and in specifying the equipment used on the same fundamental basis, there is no question whatever but what our fundamental knowledge of the resistance welding art and consequently our ability to apply it to advantage would be greatly improved in a comparatively short period of time.

AUTOMATIC WELDING IN the Construction of Diesel-Electric Locomotives*

By JOHN H. HRUSKA†

PRIOR to the advent of Diesel-electric motive power, practically all applications of arc welding in American locomotive design and maintenance were limited to parts of very minor importance. Hence, the actual construction of locomotive bodies was not successfully attempted until the perfection of Diesel-electric motive power made the combined developments economically interesting to railroad managements. However, these achievements did not become realities without consistent and admittedly radical departures in utilizing engineering materials, manufacturing processes and ultimately in methods of design or construction. Thus static and dynamic properties of materials together with processes of manufacturing unheard of a few years ago were the dominating factors on which safety and economical transportation hinged in the past and on which depends the future of modern railroading.

Diesel-electric power of today has definitely established economies in fast, long-distance transportation as well as in the other extreme which is typified by the rather slow but powerful switcher. Several hundred of these units operate at present under most strenuous conditions in railroad yards, steel mills, mines and industrial plants continuously for 23 to 24 hours a day, 7 days a week. For such application, engineering considerations required structures which were strong, resistant to vibration under heavy loads and stresses at practically any temperature to which locomotives are exposed in the various parts of the country. These anticipated properties are essentially prerequisites of the load-bearing materials as well as of the joints of various structural members, plates, sheets, etc. The time-honored controversy of riveted versus welding construction was, of course, revived, but it was soon apparent that the latter is the more desirable one because of better physical properties, easier handling and much improved appearance. In order to justify the selection for the most appealing and yet economical methods of welding, it was imperative to survey the entire field of welding with the aim of combined highest physical properties, most enduring dynamic characteristics, greatest chemical stability and other outstanding requirements upon the weld metal. In addition, the design of the locomotive had to be changed so as to permit a continuous and, therefore, time- and labor-saving procedure of welding. The outcome of these tendencies was the construction of car-body where beads could be applied effectively for the entire length of the locomotive. The two principal divisions of Diesel-electric motive power was, therefore, closely related to the development of welding processes for both groups. The Diesel-electric streamliner is at present a typical example of a multitude of short highly specialized welds, whereas the switcher embodies a much smaller number of welds but of much heavier cross-sectional area and by far the greater length. The latter development led to the application of an automatic procedure of welding, which process has been introduced by the originators, The Linde Air Products Company, under the trade name of "Unionmelt Welding." Details of set-up and procedures have been constantly improved by applying all known methods of metallurgical control throughout the development work as well as present routine inspection.

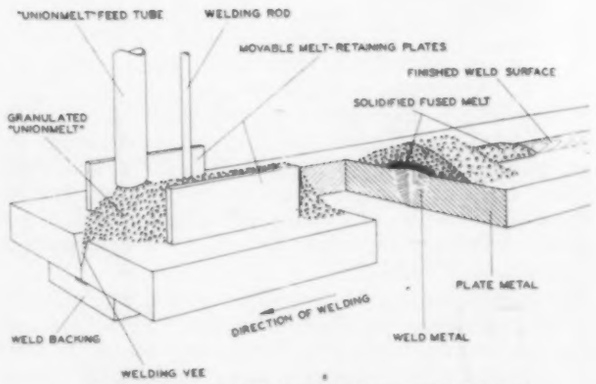


Fig. 1—Principle of Unionmelt Automatic Welding

APPARATUS AND METHODS OF PROCEDURE

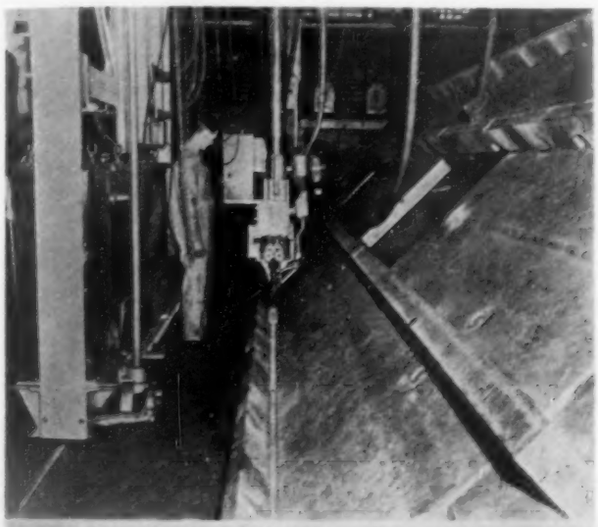
As indicated in the introductory remarks, the welding of such important parts as an underframe of the Diesel-electric switcher is governed by fundamental variables in automatic welding, namely, current intensity, current voltage, velocity of welding, size and type of welding rod and chemistry and grain size of welding flux. The process has been amply described in welding literature and reference is only being made to the illustrations shown in Figs. 1, 2, 3 and 4. It will be noted that practically all these welds are fillet welds. Their size ranges from $^1/_2$ inch to $^3/_4$ inch. The diameter of the electrode is ordinarily $^1/_4$ inch and the travel somewhere between 7 and 12 inches per minute. The voltage is about 33 to 36 v. and the current intensity at transformer 800 amp. The thickness of the plate ranges from $1^1/_2$ inches to as high as $4^1/_4$ inches. At one time or another, heavier base plates are required in order to derive at definite loads upon the power axles. In such instances it was found advisable to butt-weld $4^1/_4$-inch plates together, thus producing a plate 40 ft. 3 in. long, 10 ft. wide and,

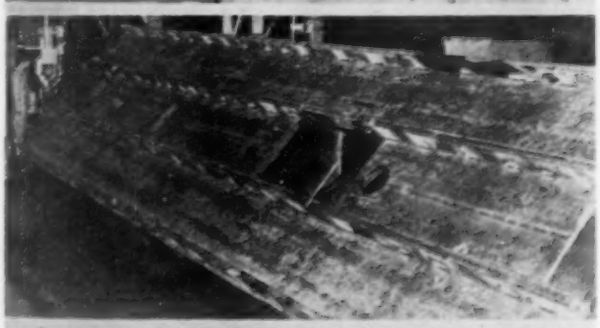
* Presented at Railroad Session of the Annual Meeting of the AMERICAN WELDING SOCIETY, Friday Oct. 27, 1939.
† Electro-Motive Corporation, La Grange, Ill.

as mentioned, 4¼ inches thick. Two single automatic butt welds laid at speeds of about 5 to 6 inches per minute make this specified joint (see Fig. 5). In order to overcome the latter mentioned internal notch effect, the beads overlap thus representing practically one solid plate.

CHEMICAL AND MECHANICAL PROPERTIES OF AUTOMATIC WELDS

As an initial step of a rather exhaustive program of various types of tests, a complete chemical survey was made of many of the mentioned welds. From these data it is readily evident that the automatic weld shows no loss in carbon, manganese, sulphur nor phosphorus. In addition to the analytical determinations made ordinarily with welds, careful analyses of nitrogen were also conducted in the course of these metallographical studies.





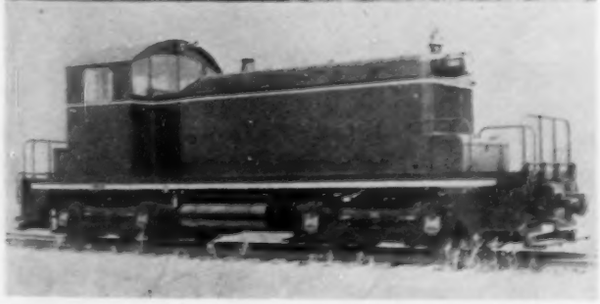


Fig. 2 (Top)—Close-Up of Automatic Welder Showing Welding Head and Position of Underframe for Fillet Welding

Fig. 3 (Center)—Automatic Welding of Underframe for Modern Diesel-Electric Switcher

Fig. 4 (Bottom)—Modern Diesel-Electric Switcher Showing Welded Underframe

Table 1—Chemical Analysis of Weld and Parent Metals of Automatic Welds

	Parent Metal	Weld Metal
Carbon, per cent	0.21	0.20
Manganese, per cent	0.47	0.46
Silicon, per cent	0.01	0.38
Phosphorus, per cent	0.022	0.017
Sulphur, per cent	0.019	0.021
Nitrogen, per cent	0.017	0.008
Silicates, per cent	0.008	0.005

Table 2—Physical Properties of Automatically Produced Weld Metal

Property	Parent Metal "As Welded"	All Weld Metal "As Welded"	All Weld Metal Annealed at 1650° F.
Tensile strength, psi	62,650	66,720	62,050
Yield strength, psi	39,800	40,150	34,250
Elongation of 2 in., %	34.9	37.1	37.8
Reduction of area, %	58.9	62.1	64.9
Brinell hardness	123	122	112
Rockwell B-hardness	71.6	70.3	66.9

It is interesting to note that the highest concentration of total nitrogen found in any of the automatic welds used in the construction of Diesel-electric locomotives was 0.017%. The average range is somewhere between 0.004% and 0.006%. Chemical and metallographical advantages of automatically produced welds are perhaps best realized from the resultant physical characteristics of the metallic matrix. Plates of various thicknesses were removed from commercially produced automatic welds, cut according to standard specifications and tested in the laboratory. All weld test bars showed results given in Table 2 and are shown in Fig. 6. Additional tests were made with Charpy impact specimens at various temperatures, the results of which are indicative of the high quality of the welds at temperatures as low as −100° F. Hardness tests may be conducted by means of either the Brinell or Rockwell testers because of the size of the specimens produced. The hardness gradient rarely exceeds 20 B. H. N. Numerous cross sections in a fillet and a butt weld of various sizes indicated clearly the freedom of any deficiency or non-deformity of the texture (see Fig. 7). Microstructures of the transition zone between the weld proper and the adjacent thermally affected area also prove the correctness of this contention. X-ray studies were also made of welds of various sizes and they invariably confirmed findings by the metallographical work carried out so far (see Fig. 8). The frequent questioning of the metallurgical effect of the rather coarse crystallinity of the weld proper as compared with the parent metal has substantiated a careful research into the stress conditions of the various principal zones of the weld. A specimen representing the butt weld of 1-inch plate was picked at random, prepared properly and subjected to the effects of monochromatic X-ray diffraction (see Fig. 9). It is clearly evident that the crystalline and stress conditions vary little, thus confirming the mechanical characteristics of the weld and its adjacent portions of the structure.

Figure 10 is a photograph taken at a spot as far away as possible from the weld, i.e., in the plate, so as to show the material with as little heat effect as possible. It will be noted that this picture represents the anticipated structure of hot-rolled, but unannealed plate.

Figure 11 represents metal close to the thermally affected zone. Some grain growth is clearly visible by

Fig. 5—Macrograph of Automatically Produced Butt Weld of 4¼ Inch Thick Plate

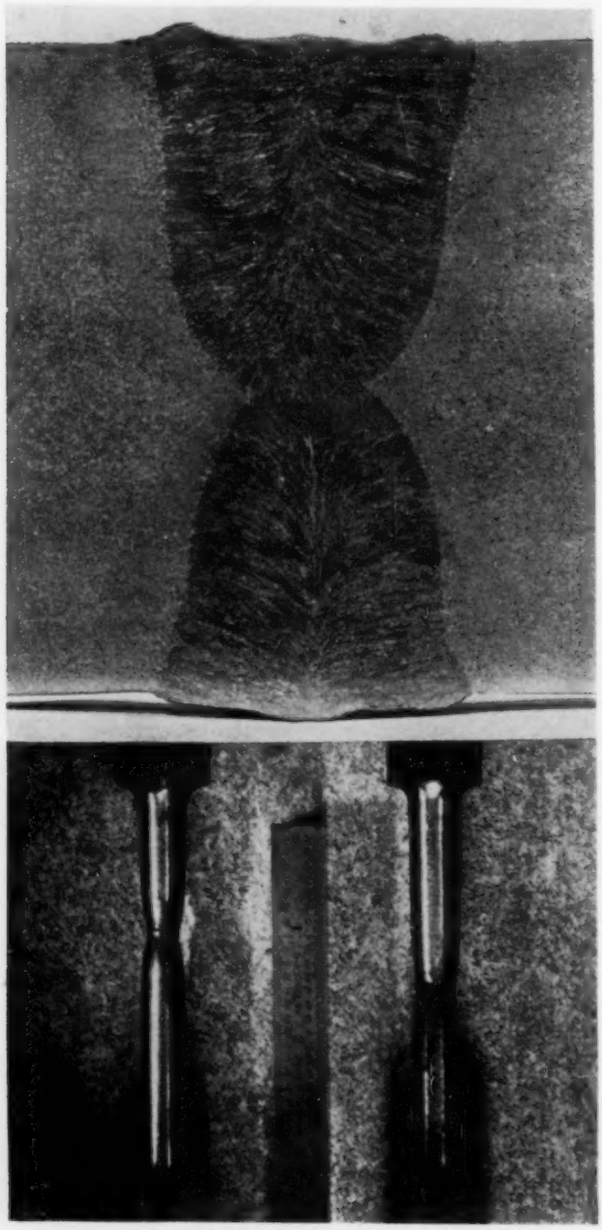


Fig. 6—All-Weld Metal Test Bars of Automatic Weld

the somewhat more pronounced half circles around the reflection of the pinhole. In addition, the radial flares indicate considerable stresses at this point.

Figure 12 illustrates that marked grain refinement and little stress exist close to the fusion area. The annealing effect immediately after welding clearly eradicated the stresses existing adjacent to the weld area—theoretically a very desirable condition.

Figure 13 shows photograph of the weld metal and is indicative of a rather large grain, besides considerable mechanical stresses.

Figure 14 gives evidence that stresses have been relieved by external strain.

FATIGUE RESISTANCE OF AUTOMATIC WELDS

Although the combined mileages of all Diesel-electric locomotives in the United States have well surpassed 30,000,000 miles since their first introduction in 1932, we may marvel at the fact that not one automatic weld failure was experienced by any of the numerous owners of this type of locomotive. The first automatic welds in

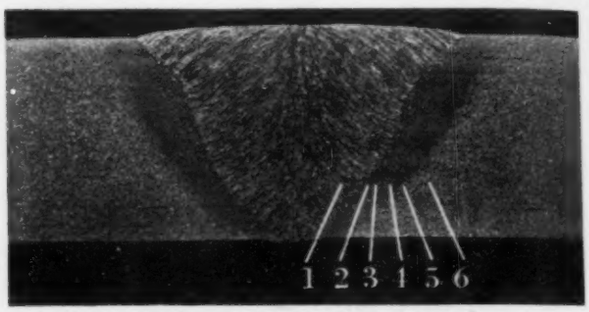


Fig. 9—Macrograph of Automatic Butt Weld Showing Locations of Monochromatic X-Ray Diffraction Tests

locomotives were made early in 1935 and while it is true that probably the major portion of the combined mileage must be apportioned to the streamliners, it must nevertheless be realized that the switchers with their automatically welded underframes haul by far the heaviest

Table 3—Fatigue Tests with Automatic Welds

Load in Lb./Sq. In.	Cycles to Failure of Weld	Cycles to Failure of Parent Metal
40,000	1,293,900	5,400,000
39,000	Over 10,000,000	Over 10,000,000
38,500	Over 10,000,000	Over 10,000,000
38,000	Over 10,000,000	Over 10,000,000
36,000	Over 10,000,000	Over 10,000,000

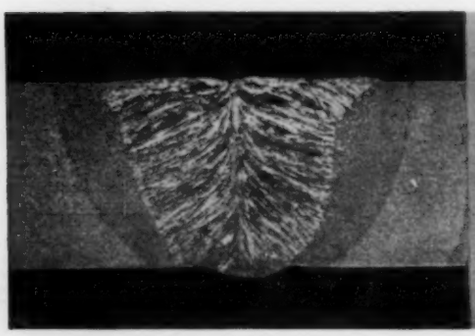


Fig. 7—Macrograph of Automatically Produced Butt Weld

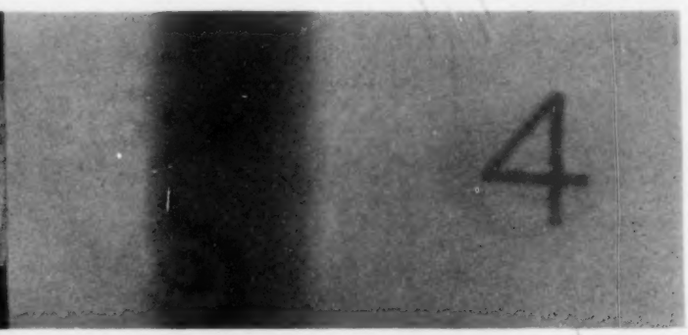


Fig. 8—X-Ray Test of Automatic Weld Shown in Fig. 7

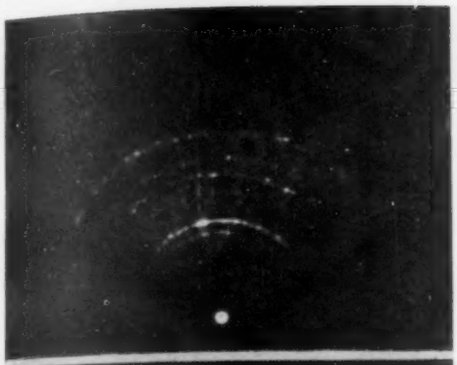


Fig. 10—Monochromatic X-Ray Diffraction Pattern of Area Marked No. 6 Fig. 9

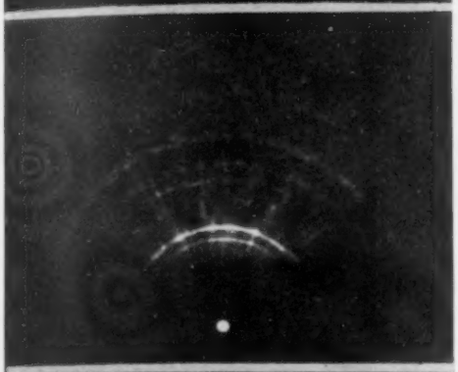


Fig. 11—Monochromatic X-Ray Diffraction Pattern of Location No. 5 in Fig. 9

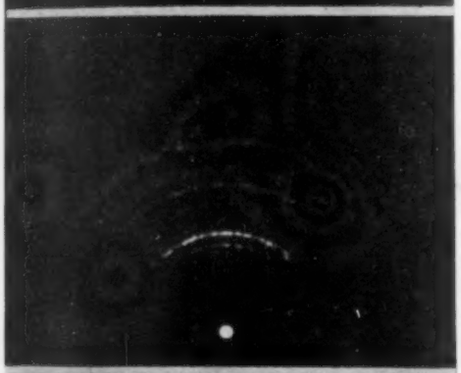


Fig. 12—Monochromatic X-Ray Diffraction Pattern of Area Marked No. 3 in Fig. 9

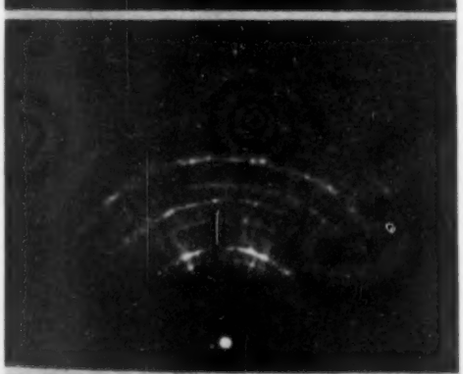


Fig. 13—Monochromatic X-Ray Diffraction Pattern of Location No. 2 in Fig. 9

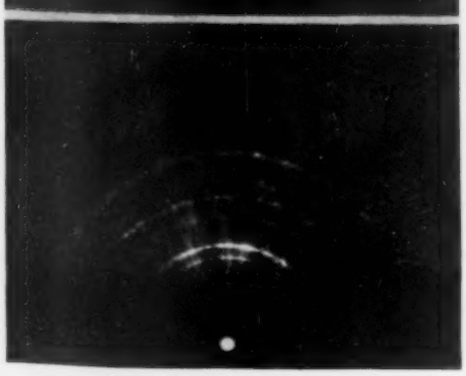


Fig. 14—Monochromatic X-Ray Diffraction Pattern of Location No. 1 in Fig. 9

loads. That no failure of automatic welds ever occurred in any railroad service of the Diesel-electric type is, therefore, by no means a fortunate coincidence. Careful investigations have been made before the general adoption of automatic welding in the construction of these locomotives. Since any rolling stock in railway service is subject to rapidly changing stresses, it was only logical to conduct specific tests of this type in which static loading was augmented by mechanical fatigue and impact. Fatigue tests were made with samples of butt-welded carbon steel as well as alloy steel plate. In all cases, the specimens required for the endurance test were taken according to the A. S. M. method of fatigue testing. The direction of the weld was perpendicular to that of the axis of the specimen. The first series of tests were made in three accurately calibrated fatigue testing machines of the R. R. Moore type, utilizing a rotating beam. The results of this work are compared with data obtained when testing the parent metal. It is evident from this comparison that the endurance properties of welds for this method of testing are practically identical with those of the parent metal. Stress relieving at 1200° F. does not affect the fatigue values to any marked extent (see Table 3).

Since the endurance properties of welds are of utmost importance in the construction of any type of locomotive, a second and more elaborate series of tests is being conducted at present by using the simple flexure type of test. In this test, the specimen of conventional dimensions and geometrical outline is based on sheet and plate stock. The machine as well as the entire set-up is shown in Fig. 15. The specimens are ground to 0.100 inch and are milled exactly to give uniform stress over the tested portion of its cantilever length. The stroke of the machine is varied to range from 0.10 to 0.50 inch while adjusting the variable throw crank or eccentric. By actual comparison, it seems that this type of endurance testing is much more satisfactory and yields much more uniform results than the customary procedure with round fatigue specimens. The difficulty of obtaining a truly comparative finish of the round specimen is favorably offset by utilizing flat specimens with both faces precisely ground on suitable surface grinders, thus permitting the production of truly comparative finishes. Besides, most fatigue phenomena in actual railway service approach this type of stressing rather than that of circular speci-

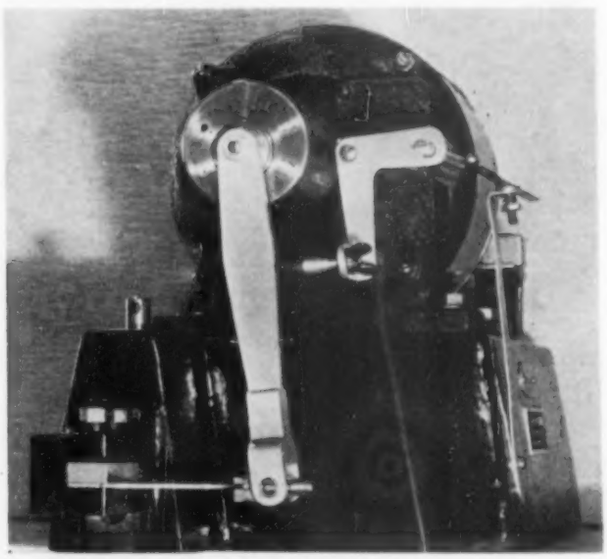


Fig. 15—Krouse Fatigue Testing Machine Used for Investigation of Endurance Properties of Welds

mens. The calculation of the endurance limit may then be accomplished by applying the principles of stress calculation from cantilever loadings.

PRACTICAL EXPERIENCES

In summing up the preceding sections, it should be realized that the somewhat lengthy investigations commented upon were prompted by the desire to develop a method of fast and yet uniform welding of heavy masses. Past experience with welds of comparative size but in other fields of industry has naturally directed our attention to determine some of the reasons of defective or cracked welds caused by intentional or accidental notches—very often in locations least suspected. This notch sensitivity is especially inherent to heavy sections and since such mass effects are more prone to localize stresses, we have studied the problem by following a definite outline of synthetically produced cracks and other deficiencies. Figure 16 shows one of these experimental joints. It is quite evident that the base of the automatic weld was stressed during the initial stages of solidification beyond its tensile strength by virtue of the void and non-metallic inclusions accumulated within that area. We have found that in order to eliminate any possibilities of cracked welds in heavy sections and their welds the following thoughts must be incorporated:

1. Elimination of any internal notches, i.e., full overlapping welds throughout the entire section (see Fig. 5).
2. Ample radii in finishing the welds to approach a distribution of stresses indicated by the well-known photoelastic work by Everett Chapman and others (see Fig. 17).
3. Positively no undercutting.
4. Clean surfaces of contact between welding parts.

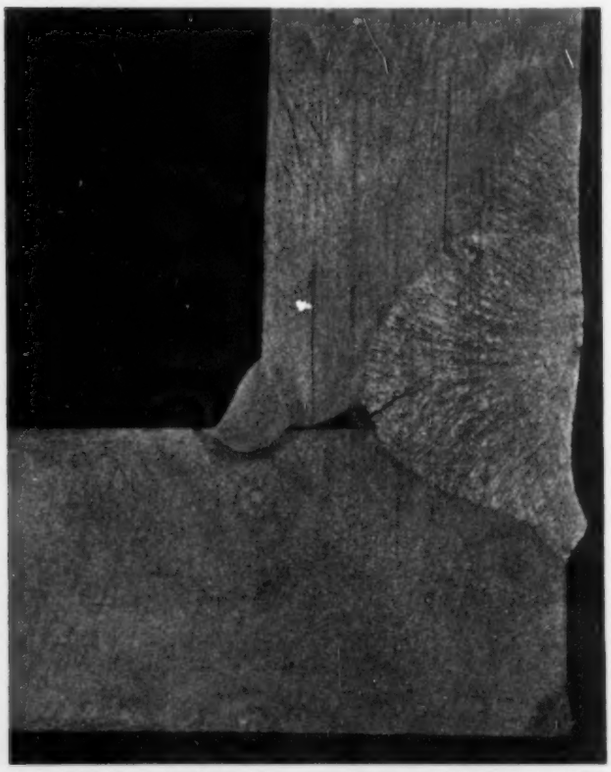


Fig. 16—Macrograph of Experimental Weld Showing Effect of Artificial Void. Vertical Lines Are Laminations in Steel Plate

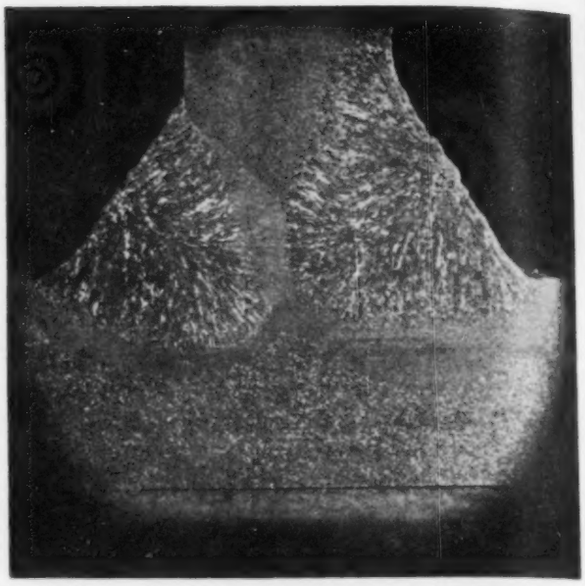


Fig. 17—Macrograph of T-Joint Showing Overlapping Automatic Welds

5 Deep penetration also helps to minimize any unwelded sections.

6. Stress relieving shall be encouraged as further measure of ultimate safety of the welded assembly.

Practical arc welders know that another prolific source of weld failures is excessive speed of the electrode during the welding process. In such cases, the base metal does not reach its melting point, thereby failing to fuse together with the metal of the rod. The weld does not penetrate or "penetration is negligible." From this viewpoint, the automatic process is an important step forward. Volumetrically speaking, the automatic welds used in our locomotive construction of the Diesel-electric type have about 170 to 230% of fused and intermixed metal in comparison with the corresponding fillet. This obviates any possibility of lack of fusion and consequent rupture of welded joints.

Table 4—Length of Automatic Welds in Diesel-Electric Switchers

	600 Hp.	900 Hp.
Side and center sills	298 ft. 0 in.	307 ft. 0 in.
Bottom plate	98 ft. 10 in.	112 ft. 2 in.
Draft gear pocket	16 ft. 8 in.	16 ft. 8 in.
Total per frame	413 ft. 6 in.	435 ft. 10 in.
Size of fillet welds	1/2 in.	3/4 in.

As a further reason of justifiable interests in the fundamentals of heavy welds, at least a few meager references are offered to actual construction data for the more outstanding examples of the described process. Underframes of switching locomotives of 600 and 900 hp. nominal rating shall again be submitted. The length of the fillet joints per underframe is thus presented in Table 4. Generous use of automatic welding is also made in the fabrication of crankcases and other major parts of Diesel engines, generators, etc., of Diesel-electric locomotives.

ACKNOWLEDGMENTS

In closing I wish to thank Mr. L. C. Sheldon of General Electric X-Ray Corp. of Chicago, for his generous assistance in conducting all the X-ray work reported herein. I also believe proper credit should be given to Mr. H. L. Hamilton, President, and Mr. Ernest Kuehn, Works Manager of Electro-Motive Corporation, for their decision in utilizing the described process.

WELDED NOZZLES AND THEIR Reinforcement*

By F. C. FANTZ† and W. G. HOOPER‡

REINFORCEMENT OF 90° WELDED NOZZLES

THE advancements in the art of welding in the last decade, both in quality of welding procedure and the proficiency of the welding operator, have convinced the piping designer as to the complete practicability of the use of welding in the design of piping systems. This confidence in welding is made evident by the almost entire elimination of cast flanged headers, tees, elbows and flanged joints, and the substitution of welded headers, welding fittings and butt welds in the modern piping design.

The various A. S. A. Codes have established definite rules governing the design of piping systems, with formulas developed for ascertaining the wall thickness of pipe, and welding fittings and the strength of butt and fillet welds. However, there is nothing in any of the A. S. A. Codes, that can be applied to the design of nozzle attached to headers or piping, that would determine when reinforcement might be necessary to compensate for the weakening of the header due to the removal of metal for the nozzle opening.

The A. S. M. E. Code for Unfired Pressure Vessels, applies primarily to the materials design and manufacture of pressure vessels such as tanks, separators, receivers, etc., and the rules of this Code governing the manufacture of this character of equipment are not intended to apply 100% to the fabrication of piping materials. However, this Code does cover the design of welded nozzles, attached to unfired pressure vessels, and it being the recognized Code with formulas governing the attachment of nozzles and the reinforcement of same when necessary; it is logical that the piping designer accept these rules and be governed in his design by Section U-59 of the Code for Unfired Pressure Vessels—Revised August 15, 1938.

90° WELDED NOZZLES

The A. S. M. E. Code for Unfired Pressure Vessels, Section U-59, Revised August 15, 1938, subject—"Nozzle Openings," covers the design of the Nozzle Openings, and a nozzle attached in compliance with the rules and conditions of Section U-59, is entitled to bear the A. S. M. E. stamp as conforming to the Code, and as being within good limits of safety.

This section is naturally extremely simple and clear to the Boiler Designer, who is using it constantly, but to the piping designer it may seem complex and the rules governing the design appear cumbersome.

With the idea in view of making this section applicable to the Piping Industry for the design and fabrication of welded nozzles attached to headers and pipe, we have clarified the various rules and have set them up in the form of simple algebraic equations, with graphs for the calculation of the several constants used. The following treatise is to apply only to headers in sizes from 6.625 inch O.D. to 24 inch O.D. inclusive.

The procedure is divided into two sections.

Section I.—To determine whether the header or pipe requires reinforcement.

Section II.—In case reinforcement is necessary, how much additional metal must be added and by what method; extra welding, ring or saddle.

Section I

1st Step.—In case the wall thicknesses of the header or nozzle are not specified, then calculate the wall thicknesses by the Schedule Number System in accordance with A. S. A.-Bulletin B-16(latest revision)using the maximum working stress values, as given in Table U-3 for the specified temperature and working pressure.

Fig. 1

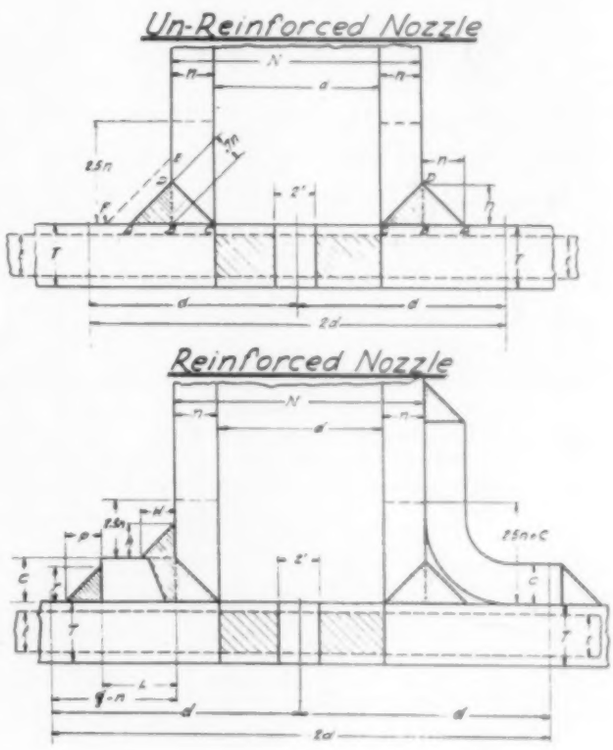


Fig. 2

* Presented at Annual Meeting, A. W. S., Chicago, Oct. 23 to 27, 1939. The intent of this paper is to submit for consideration a simplified method for ascertaining the necessity of nozzle reinforcing, and also the amount and type of reinforcement required to comply with U-59 of the A. S. M. E. Boiler Construction Code for Unfired Pressure Vessels, as it applies to the Pipe Fabrication Industry.

† Vice-President, Midwest Piping and Supply Co. Inc., St. Louis, Mo.

‡ Vice-President, Midwest Piping and Supply Co. Inc., St. Louis, Mo.

2nd Step.—Calculate the minimum wall thickness of header in accordance with Formula given in U-20-a for specified temperature and working pressure,

$$t = \frac{PD}{2S \times E} = \frac{PD}{2S \times .90} = \frac{PD}{1.8S} \quad (1)$$

t = Minimum wall thickness inches
P = Internal working pressure psi
D = Outside diameter, inches
S = Allowable working stress psi—Plate D or U-3
E = Efficiency = 90%—U-59-g-1 and 2.

3rd Step.—Reference Fig. 1, and U-59-g-2. Calculate the cross-sectional area of the finished nozzle opening in the header (U-59-g-2), as follows:

$$\text{Cross-sectional area} = (d - 2) \times t \quad (2)$$

Determine the effective cross-sectional area of the nozzle, as follows (U-59-g-1-b)

$$\text{Nozzle cross section} = 2 \times 2^1/_2 n \times n = 5n^2 \quad (3)$$

where n = wall thickness of nozzle, inches.

According to U-59-g-2, no reinforcement will be necessary providing the cross-sectional area of the nozzle ($5n^2$) is either equal to or greater than the cross-sectional area of the header $(d - 2)\,t$, and expressed as when

$$5n^2 \geqq (d - 2)t \text{ (no reinforcement).} \quad (4)$$

4th Step.—Reference Fig. 1, and U-59-1-*a* and *b*. According to this rule no reinforcement will be required, providing that the total cross-sectional area of the nozzle attachment, including the header, nozzle and welds is equal to or greater than the cross section of the header, equivalent to a rectangle whose length is twice the inside diameter of the finished opening minus 2 inches, and whose width is equal to the minimum wall thickness of header (t) (See Formula 1—Second Step); and expressed as follows:

Criterion cross-sectional area of header

$$\text{(U-59-g-1)} = (2d - 2 \text{ inches}) \times t \quad (5)$$

Cross sections of attachment

$$\text{Cross-sectional area in header} = (2d - d) \times T \quad (6)$$

Where T = Actual wall thickness of header

$$\text{Cross-sectional area in nozzle} = 2 \times 2^1/_2 n \times n \quad (3)$$

$$\text{Cross-sectional area in welds} = 2 \times n \times n \times 0.5 \quad (7)$$

$$\text{The total of Forms 6, 3 and 7} = dT + 6n^2 \quad (8)$$

When $dT + 6n^2 \geqq (2d - 2 \text{ inches}) \times t$—
No reinforcement (9)

5th Step.—In accordance with U-59-g-2 the strength of the attachment to the header of each separate part entering into the fabrication of a reinforced opening shall be at least equal to or greater than the tensile strength of the cross section of the reinforcing part expressed by

$$(d - 2) \times t \times S \quad (10)$$

As the completed attachments strength consists of 3 parts (see Figs. 1 and 2) and are as follows:

(*a*) Strength of the cross-sectional area of the nozzle including reinforcing

$$= 2 \times 2^1/_2 n \times n \times S \quad (11)$$

(*b*) Strength of the weld ABD in Tension

$$= \pi(d + 2n) \times 0.50 \times n \times 0.90 \times S \quad (12)$$

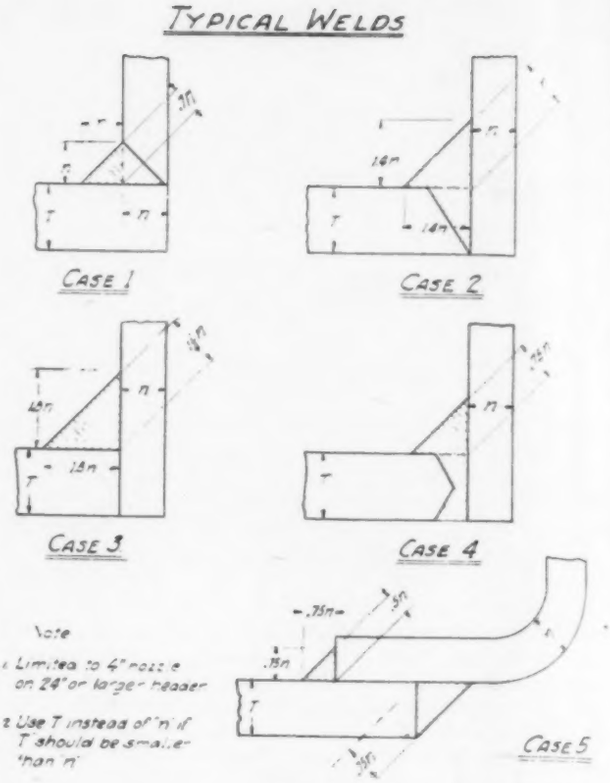

TYPICAL WELDS
CASE 1
CASE 2
CASE 3
CASE 4
CASE 5
Note
1 Limited to 4" nozzle on 24" or larger header
2 Use T instead of 'n' if T should be smaller than n

Fig. 3

(*c*) Strength of the weld ABD in Shear

$$= \pi(d + 3n) \times 0.50 \times 0.70n \times 0.80 \times 0.90 \times S \quad (13)$$

5th Step.—Simplifying
$(d - 2)tS$ (10) must be equal or less than each of the following:

$5n^2S$	(11)	condensed
$1.41\,(d + 2n)nS$	(12)	"
$0.79\,(d + 3n)nS$	(13)	"

In these calculations the butt weld BCD joining the nozzle to the header is considered a part of the nozzle cross section and is not included in the weld area.

The fillet weld ABD is considered as a fillet strength weld (U-59-h and Fig. 3, Case 1).

However, any weld metal in excess of weld ABD may be considered as additional reinforcement.

SUMMARY

By condensing the various steps in the preceding calculations, five separate cases can be developed to determine the necessity of reinforcement in compliance with U-59. These cases are given below in an algebraic form,

Case 1	$5n^2 \geqq (d - 2)t$	(4)
Case 2	$dT + 6n^2 \geqq (2d - 2)t$	(9)
Case 3	$5n^2S \geqq (d - 2)tS$	(11)
Case 4	$1.41\,(d + 2n)nS \geqq (d - 2)tS$	(12)
Case 5	$0.79\,(d + 3n)nS \geqq (d - 2)tS$	(13)

And if the values on the left of the sign $\geqq$ for each of the 5 cases are all equal to or greater than those on the right, then no reinforcing will be required.

Inside Diameter of Nozzle Minus 2 Inches (D − 2)

Size Nozzle, In.	Standard Weight $^1/_8$ In. O.D.	Extra Strong $^1/_8$ In. O.D.	Double Ex. Str. 3 In. to 8 In.	Schedule Numbers 30	40	60	80	100	120	140	160
$2^1/_2$	0.464	0.323			0.464		0.323				0.125
3	1.070	0.900	0.300		1.070		0.900				0.630
$3^1/_2$	1.550	0.730	0.896		1.550		1.360				
4	2.030	1.830	1.150		2.030		1.830		1.63		1.440
5	3.050	2.820	2.313		3.050		2.820		2.563		2.313
6	4.070	3.760	2.900		4.070		3.760		3.500		3.190
8	6.070	5.625	4.880	6.070	5.980	5.810	5.625	5.440	5.190	5.000	4.810
10	8.140	7.750		8.140	8.020	7.750	7.564	7.314	7.060	6.750	6.50
12	10.090	9.750		10.090	9.940	9.630	9.380	9.060	8.750	8.500	8.126
14	11.250	11.000		11.250	11.130	10.814	10.500	10.130	9.880	9.500	9.186
16	13.250	13.000		13.250	13.000	12.690	12.310	11.940	11.560	11.126	10.876
18	15.250	15.000		15.130	14.880	14.564	14.130	13.690	13.314	12.876	12.500
20	17.250	17.000		17.000	16.814	16.375	15.940	15.500	15.000	14.500	14.126
24	18.250	21.000		20.880	20.630	20.130	19.560	19.000	18.500	17.880	17.376

Fig. 4

In case any one of the values given on the left of the sign $\lesseqgtr$ for each case is smaller than the one on the right, reinforcement must be added.

This reinforcement can be accomplished by three different methods, i.e.

(*a*) By adding additional weld metal.

(*b*) By welding a ring or collar to the header and to the nozzle.

(*c*) By the use of a reinforcing saddle, welded to the header and to the nozzle.

5th Step.—It was discovered by numerous Test Calculations that when Case 1—Formula 4 complied with the Code that Cases 2, 3, 4 and 5 also complied with their respective rule.

This being the case, the Formula $5n^2 \lesseqgtr (d-2)t$—(4) Case 1, will be the basis for the balance of the computations to ascertain the amount of reinforcing necessary for Code compliance.

6th Step.—Resolve the Formula $5n^2 \lesseqgtr (d-2)t$ into the equation

$$5n^2 - (d-2)t = \pm Q, \qquad (14)$$

Q represents the total area of reinforcement that must be added for Code Compliance.

Note that when Q is positive $(+)$ then no reinforcing is necessary and when Q is negative $(-)$ then reinforcing must be added.

Assuming in this case that Q is negative and, therefore, reinforcing is necessary, but that the amount of reinforcement required is exceedingly small and that this reinforcement can be in the form of additional weld metal by increasing the cross-sectional area of the fillet weld *ABD* to *FBE*, so that the area *FADE* is equal to one half the area Q. See Fig. 1.

7th Step.—When the area Q is so great as to make the addition of so much weld metal impracticable, then the additional reinforcing must be in the form of either a ring or a reinforcing saddle.

The Ring or Collar shown, Fig. 2, must have an area including attachment welds equivalent to the area Q (Formula 14) U-59-g-1 (*a* and *b*) provides certain limiting dimensions of this reinforcement area Q for which credit will be given, as follows;

(*a*) Credit only will be allowed for that portion of the reinforcement on the header that may extend longitudinally parallel to the horizontal axis of the header for a distance on each side of the center line of the opening equal to the actual inside diameter (d) of the opening in the header in the finished construction.

(*b*) Credit only will be allowed for that portion of the reinforcement that may extend along the tubular portion of the nozzle for a distance equal to $2^1/_2$ times the wall thickness (n) of the nozzle, measured from the surface of the header or from the reinforcement.

Therefore, the limiting length of the reinforcement can be stated as $0.5d-n$ which includes the fillet weld at the outer edge of the reinforcement, and the actual length of the ring cross section would be $0.5d-n-p$ or L as in Fig. 2.

The height or thickness (C) of the ring is based arbitrarily on values given in Table U-7 Minimum Thickness

MAXIMUM ALLOWABLE WORKING STRESS (S)

A.S.M.E. CODE REVISED AUG. 15, 1938.

TABLE P-9 or U-3.

TEMP. DEG. F	CARBON STEEL PIPE Lap Weld	SEAMLESS Grade A	Grade B	CARBON MOLY GRADE P1
-10° to 650°	9000	9400	12000	11000
675°	8800	9300	11800	
700°	8500	9100	11400	
725°	8200	8850	11000	
750°	7800	8600	10400	
775°		8300	9800	
800°		7900	9100	11000
825°		7400	8300	10750
850°		6800	7400	10500
875°		6200	6500	10250
900°		5600	5600	10000
925°		4700	4700	9000
950°		3800	3800	8000
975°		2900	2900	6500
1000°		2000	2000	5000
Min.T.S.	45000	47000	60000	85000

MINIMUM THICKNESS REINFORCING RING OR FLANGE ASME CODE TABLE P-14 or U-7.

Thickness Header Wall	Thickness (Min.) Ring or Flange
1/8	1/8
3/16	3/16
1/4 to 11/32	1/4
3/8 to 13/32	5/16
7/16 to 15/32	3/8
1/2 to 9/16	7/16
5/8 to 3/4	1/2
7/8	5/8
1	11/16
1-1/8 to 2	3/4
OVER 2	1

Fig. 5

of Independent Riveted Reinforcing Rings or Flanges (see Fig. 6).

Then the actual area of the ring can be expressed as $L \times C$, and as area Q determines the Compliance with the Code $L \times C$ must be equal to or greater than $Q/2$.

Attention is called to the fact the limit $2^1/_2 \times n$ has been increased by the Ring Thickness C (see *b*) then the nozzle cross-sectional area is equivalent to $5n^2 + 2nC$ and should be given credit in determining the value of L.

METHOD OF REINFORCEMENT CALCULATION SIMPLIFIED

To simplify the calculations as described in Sections I and II to determine whether or not a header requires reinforcement, and if so how much, in order to comply with the A. S. M. E. Code for Unfired Pressure Vessels—Section U-59; simple algebraic equations, with Tables and Graphs have been developed. Refer to Fig. 2.

When $5n^2 \geqq (d - 2) \times t \times \frac{P}{1000}$ no reinforcement will be required, but when $5n^2 < (d - 2) \times t \times \frac{P}{1000}$ reinforcement must be added, and the total cross-sectional area (Q) on both sides of the nozzle cross section $5n^2 - \frac{(d - 2)tP}{1000} = \pm Q$, the positive sign indicates that no reinforcing is needed, and the negative sign indicates the need of reinforcing and to the value of Q.

$Q/2$ is limited by the area $\left(\frac{d}{2} - n\right) \times C$ in the above formulas,

n = wall thickness of nozzle, inches

$5n^2$ = cross-sectional area of nozzle and attachment weld. See Fig. 7

d = inside diameter of nozzle or finished opening in header, inches

$d - 2$ inches = inside diameter of nozzle minus 2

A.S.T.M. DESIGNATION A 106-36

TABLE I. - DIMENSIONS OF LAP-WELDED AND SEAMLESS STEEL PIPE FOR HIGH-TEMPERATURE SERVICE.[a]

Note:--The decimal thicknesses listed for the respective pipe sizes represent their nominal or average wall dimensions and include an allowance for mill tolerance of 12.5 per cent under the nominal thicknesses.

Nominal Pipe Size, In.	Std. Pipe and OD Sizes 3/8" Thick	Ex. Strg. Pipe and OD Sizes 1/2" Thick	Dble. Ex. Strg.	Nominal Wall Thickness, In.									
				Schedule Number[b]									
				10	20	30	40	60	80	100	120	140	160
1/8	.068	.095					0.068		0.095				
1/4	.088	.119					0.088		0.119				
3/8	.091	.126					0.091		0.126				
1/2	.109	.147	.294				0.109		0.147				0.187
3/4	.113	.154	.308				0.113		0.154				0.218
1	.133	.179	.358				0.133		0.179				0.250
1-1/4	.140	.191	.382				0.140		0.191				0.250
1-1/2	.145	.200	.400				0.145		0.200				0.281
2	.154	.218	.436				0.154		0.218				0.343
2-1/2	.203	.276	.552				0.203		0.276				0.375
3	.216	.300	.600				0.216		0.300				0.437
3-1/2	.226	.318	.636				0.226		0.318				...
4	.237	.337	.674				0.237		0.337		0.437		0.531
5	.258	.375	.750				0.258		0.375		0.500		0.625
6	.280	.432	.864				0.280		0.432		0.562		0.718
8	.277	.500	.875		0.250	0.277		0.406	0.500	0.593	0.718	0.812	0.906
8	.322						0.322						
10	.307	.500			0.250	0.307		0.500	0.593	0.718	0.843	1.000	1.125
10	.365						0.365						
12	.330	.500			0.250	0.330	0.406	0.562	0.687	0.843	1.000	1.125	1.312
12	.375												
14 OD	.375	.500		0.250	0.312	0.375	0.437	0.593	0.750	0.937	1.062	1.250	1.406
16 OD	.375	.500		0.250	0.312	0.375	0.500	0.656	0.843	1.031	1.218	1.437	1.562
18 OD	.375	.500		0.250	0.312	0.437	0.562	0.718	0.937	1.156	1.343	1.562	1.750
20 OD	.375	.500		0.250	0.375	0.500	0.593	0.812	1.031	1.250	1.500	1.750	1.937
24 OD	.375	.500		0.250	0.375	0.562	0.687	0.937	1.218	1.500	1.750	2.062	2.312

[a] Table I is the recommendation of the Sectional Committee on Standardization of Dimensions and Material of Wrought-Iron and Wrought-Steel Pipe and Tubing, functioning under the procedure of the American Standards Association A.S.A. Project No.: B36.

[b] The schedule numbers indicate approximate values of the expression: $1000 \times \frac{P}{S}$; where P = the internal pressure in pounds per square inch and S = the allowable fiber stress in pounds per square inch.

April 1, 1939

Fig. 6

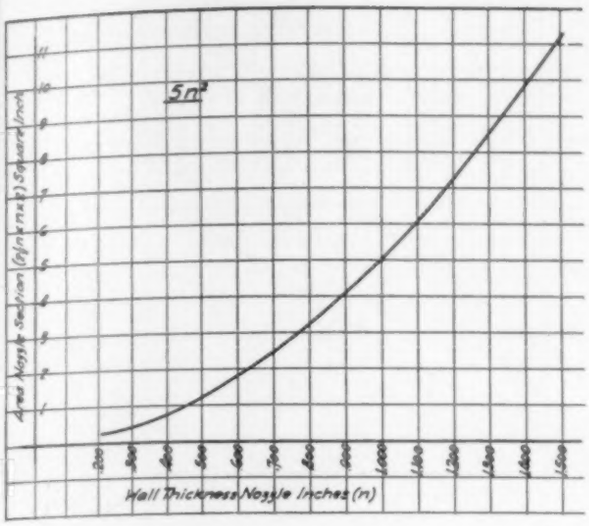


Fig. 7

inches in accordance with U-59-g. See Table in Fig. 4

t = minimum allowable wall thickness of header per 1000 lb. of Internal Pressure. See Figs. 8 and 9

P = internal working pressure psi

Q = required cross-sectional area of reinforcement on both sides of nozzle, cross section, one side $-Q/2$

C = thickness of reinforcing ring. See Fig. 6

EXAMPLE

Assume 8.625 inches O.D. nozzle to be attached to a 12.75 inch header.

Working Pressure 500 psi at 700° F.

Material—A. S. T. M. Spec. A-106—Grade A—Seamless.

No wall thickness specified.

Section I—1st Step

Schedule No. = $1000 \times P/S$—for S—see Fig. 5
= $1000 \times 500/9100$
= No. 60

Then in accordance with A. S. A.—B-16 for Sch. No. 60 the wall thickness of nozzle = 0.406 inch = n, the wall thickness of header = 0.562 inch = T and the inside diameter of nozzle or the finished opening in header = 7.83 inches = d.

Section I—2nd Step

Ascertain the minimum wall thickness (t) of header, by Formula 1.

$t = PD/1.8S$
$= 500 \times 12.75/1.8 \times 9100$
$= 0.38$ inch

Section I—3rd Step

Cross-Section Area in Header $(7.83 - 2) \times 0.38$	= 2.22	(2)
Cross-Section Area in Nozzle $2 \times 2^1/_2 \times 0.406 \times 0.406$	= 0.82	(3)
Reinforcement necessary	1.40 Sq. In.	

Section I—4th Step

Cross-Section Header $(15.66 - 2) \times 0.38$ =	5.19	(5)

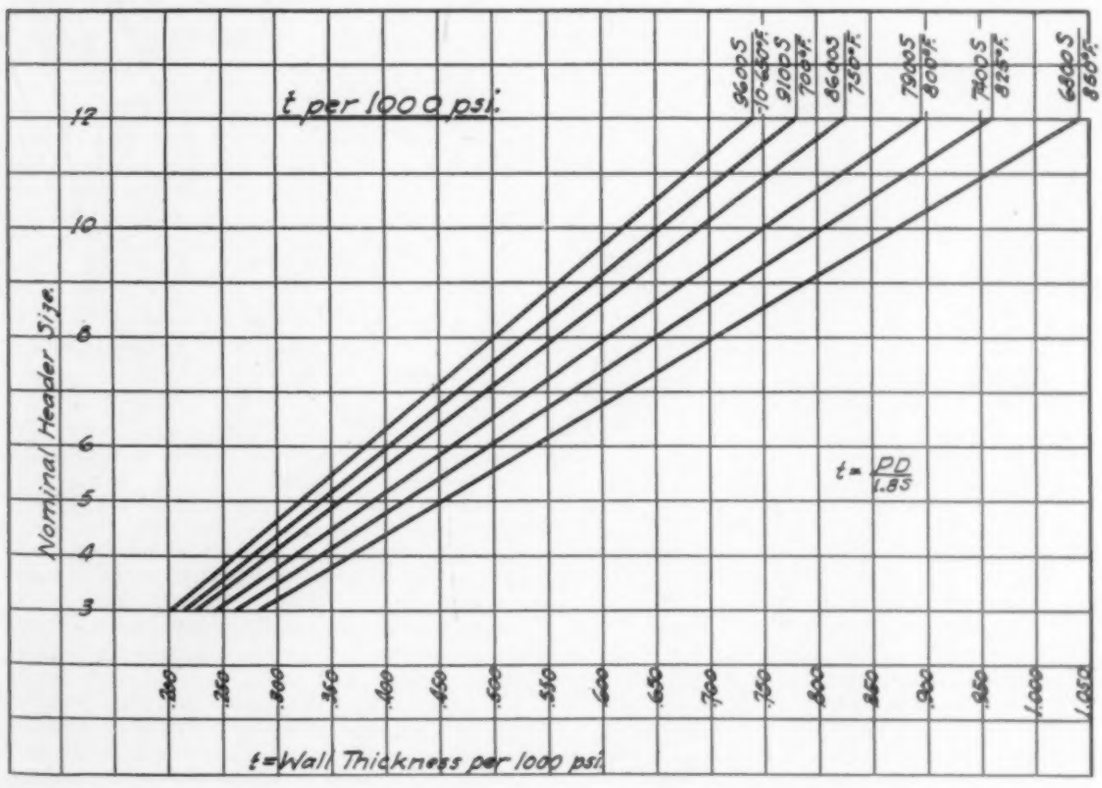


Fig. 8

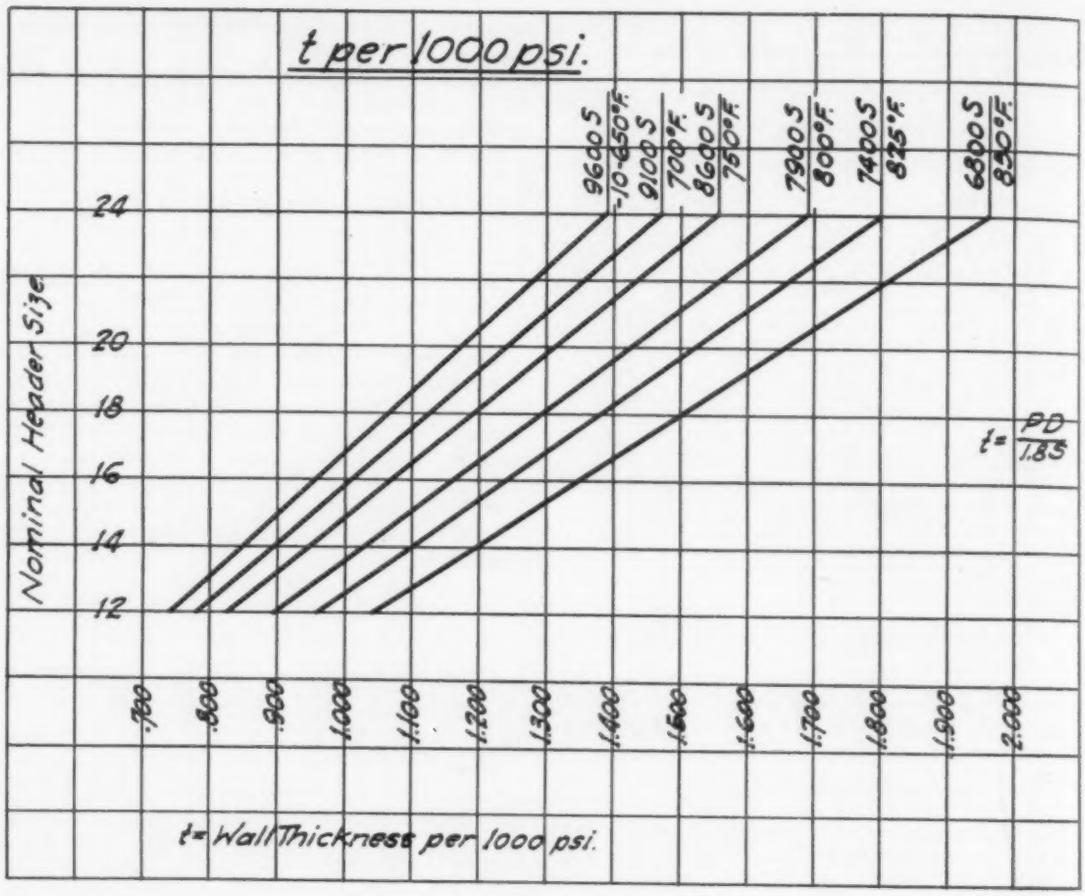


Fig. 9

Cross Sections of Attachment

Cross-Section Header

$(15.66 - 7.83) \times 0.536 = 4.20$ (6)

Cross-Section Nozzle $5n^2 = 0.82$ (3)

Cross-Section Welds

$2 \times 0.406 \times 0.406 \times 0.5 = 0.16$ (7)

5.18

0.01

According to this test, reinforcing would be required but so little as to be negligible.

Section I—5th Step

Strength of Section

$(7.83 - 2) \times 0.38 \times 9100$ psi = 20,202 lb.

Strength of Nozzle Cross Section

$5 \times 0.406 \times 0.406 \times 9100$ psi = 7508 lb.

Strength of Weld in Tension

$\pi (7.83 + 0.812) \times 0.50 \times 0.406 \times 0.90 \times 9100 =$ 46,037

Strength of Weld in Shear

$\pi(7.83 + 1.218) \times 0.50 \times 0.7 \times 0.406 \times 0.90 \times 0.80 \times 9100 = 26,481$

From the above it is evident that the weld strength is ample, but the nozzle strength is less than the header strength, however, this fact was demonstrated by the comparison made in the 3rd Step.

From the calculations in the 3rd Step it was found that in order to comply with the Code 1.4×0.50 sq. in. of reinforcing must be added to each side of Fig. 2.

The outside limits for the width of the ring would be $7.83 \times 0.50 - 0.406 = 3.51$ inches but as only 0.70 sq. in. will be required on each size and using a ring thickness of 0.500 inch it is evident that a ring $1^1/_2$ inches wide, measuring from the outside of nozzle to end of ring, by $^1/_2$ inch thick will give more than ample strength to comply with the Code.

The computations required for this example, make its solution long and tedious and a comparative solution by the simplified method is given.

Required amount of reinforcing, if any, for an 8-inch nozzle Sch. No. 60 or 0.406 inch to be attached to a 12-inch header 0.562-inch wall, operating at 500 psi at 700° F. Grade A Seamless Steel Pipe given the Formula

$$5n^2 - \frac{(d-2)tP}{1000} = \pm Q \text{ sq. in.}$$

$(d - 2) = 5.81$—Fig. 4 for 8-inch Sch. No. 60

$t = 0.76$—Fig. 8 for 12-inch header at 700°

$P = 500$ psi—As given

$5n^2 = 0.80$—Fig. 7

Substituting in the Formula—

$$0.80 - \frac{5.81 \times 0.76 \times 500}{1000} = -1.40 \text{ sq. inches}$$

and as 1.40 is negative then reinforcing will be required and to that amount.

As Q is the total cross-section area of the needed reinforcing, then $Q/2$ would be the cross section on one side.

Then $1.40/2 = 0.70$ sq. in. and selecting $^1/_2$ inch as the thickness of the reinforcement, the width would then be 1.4 inch or say $1^1/_2$ inch—thereby complying with the Code.

The strength of the header only has been considered, and the method, and amount of reinforcement necessary to strengthen the nozzle, should be considered.

Where the diameter of the nozzle is equal or near the diameter of the header there is a considerable increase in

BRANCH INTERSECTION WELD REINFORCED WITH WELDING SADDLE

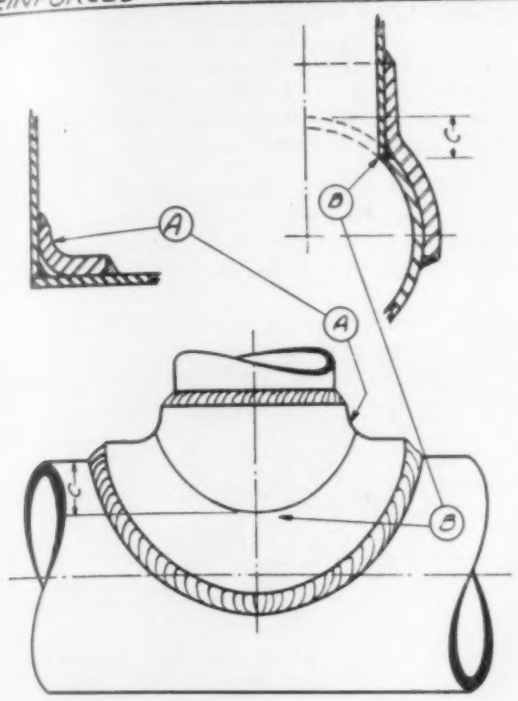


Fig. 10

area at the intersection, causing a highly stressed area (see Section C, Fig. 10).

It should be remembered that there is a considerable difference in the problem as presented by Vessel Construction as against Welded Pipe Assemblies. In the design of nozzle connections for boilers and pressure vessels, the nozzle being of relatively short length, is generally of heavier wall thickness, which compensates for the increased area at this point.

Note: Connections such as water or fire tubes are not considered.

The nozzle on this type of design is generally of much smaller diameter than the vessel, and the highly stressed area is, of course, much less.

The design of Welded Piping presents a problem which, no doubt, was not specifically considered by the A. S.-M. E. Boiler Construction Code. Nozzle intersections on piping are generally constructed of tubing material of the wall thickness as that demanded in the line by the pressure and temperature conditions. This makes it necessary to reinforce at any point where an abnormal strain is set up due to the design of the intersection.

Recent tests conducted by Engineering Offices and Manufacturers in connection with A. S. M. E. Committee work have demonstrated that the flat portion shown in Section C, Fig. 10 has deformation to a point where additional reinforcement is necessary. This can be accomplished by having a sleeve or collar encircling the nozzle intersection and made a part of or attached to the ring section on the header. This sleeve or collar may not be necessary where the nozzle diameter is below 75% of the header diameter. It is true that the ring reinforcement of the header and the welding necessary to attach it will reinforce the nozzle to some extent, particularly on the smaller diameter of the nozzles.

When a pipe line is in use, stresses are concentrated at the point of intersection, caused by expansion and contraction of the various parts of the piping assembly. It is thought the saddle type of reinforcement with the collar encircling the nozzle will minimize and better distribute these stresses.

There is available on the market nozzle reinforcing saddles consisting of a collar integral with the ring or saddle, thereby combining the nozzle reinforcing collar and the reinforcing ring described in Step 2 into one attachment (see Right Hand Section, Fig. 2). As the collar of the saddle is fillet welded to the nozzle and the ring is welded to the header, we believe that this type of reinforcement should be given equal value as the ring type when applied to a header, plus additional reinforcement to compensate for the flat section on the nozzle and localized stresses set up due to expansion and contraction.

Discussion of Paper on Welded Nozzles and Their Reinforcement

By ARTHUR McCUTCHAN†

THE methods proposed in this paper to determine the need for reinforcement of welded branch connections and the means suggested to provide such reinforcement are of related interest to piping designers. As is natural when definite design rules are not provided by some code body, differences in interpretation of design principles result. While the practice followed by Detroit Edison engineers is based on the same Boiler Code rules, it might be said to follow the *spirit* rather than the *letter* of the law. In general, the result is to provide somewhat greater reinforcement than would be found necessary by the formulas proposed in this paper.

By the spirit of the law is meant adherence to the principle of replacing metal removed from the header by an equivalent cross section of metal in the nozzle, weld and supplementary reinforcement. The only arbitrary assumption carried over from the Boiler Code is the boundary limits within which reinforcement can be considered as effective.

In computing the necessary thickness of header and nozzle for a given pressure and temperature condition, it would seem to the writer that the Code for Pressure Piping formula should be used rather than the formula given in Par. U-20 of the Unfired Pressure Vessels Code. The latter employs an efficiency factor of 90 per cent which is meaningless for seamless pipe but does not include an allowance for corrosion. These factors more or less compensate for each other, although the Code for Pressure Piping formula appears to the writer to be more logical for pipe work. The thickness determined by either formula is the minimum thickness on inspection, which will be $12\frac{1}{2}$ per cent or more under the nominal thickness depending on how closely service conditions approach the available schedule thickness, whereas the authors seem to have used the term "actual" as synonymous with "nominal."

Since the need for reinforcement must, in general, be determined in advance of assemblying the actual pipe, it would seem that the minimum thickness permissible on inspection rather than the nominal thickness should be used in the formulas proposed in this paper where "actual

† Engineering Division, Detroit Edison Co.

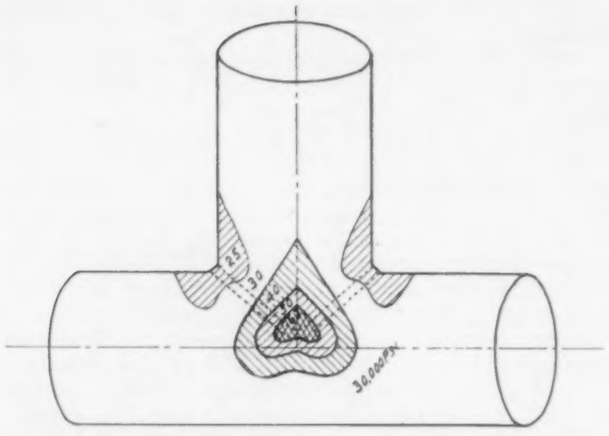


Fig. 1—Stress in Outer Surface of 8 x 8 In. Unreinforced Manifold Schedule 80 Pipe, Internal Pressure 3412 Psi

thickness will depend upon how closely the service conditions approach the design condition for the particular schedule of pipe used. Incidentally a common practice is to use short sections of heavier walled pipe at welded branch connections to provide integral reinforcement.

In computing the cross-sectional area of metal cut from the header which should be compensated for, the writer has never taken advantage of the deduction of 2 inches permitted in the Boiler Code since there seemed to be no experimental evidence to justify such deduction. On the other hand, repeated pressure loadings on test drums‡ have demonstrated that failure is initiated at small holes such as were required for test connections. In the absence of definite proof to the contrary, it would seem a safer assumption to neglect this deduction of a 2-inch hole.

The tests referred to by the authors as having been conducted by "Engineering Offices and Manufacturers in connections with A. S. M. E. Committee Work" have indeed demonstrated the need for additional reinforcement of the sides of full-size branch connections. The results obtained from strain gage measurements on an 8-inch Schedule 80 Grade B carbon steel test manifold before applying the reinforcing ring are especially informative. The heart-shaped contour lines shown in Fig. 1 indicate that the sides of the manifold have a definite tendency to assume a spherical shape.

As a result of these tests a new style of reinforcement was developed by the writer's company which is intended to prevent failure in or adjacent to the welded branch connection and to limit side distortion within acceptable limits. The reinforcement consists of a ring and side plates. Figure 2 shows a completed 10 x 10-inch welded branch connection consisting of Schedule 80 pipe made with this type of reinforcement.

While the saddle type of reinforcement advocated by the authors will cover much the same area as this reinforcement with side plates, the writer questions whether a saddle really provides the necessary support at the flat sides of the branch connection. Where pulsating loads or high rates of creep are encountered the lack of attachment of the saddle to the manifold itself around the periphery of the hole that is being reinforced would seem to be a disadvantage in that any support has to be bridged across through a relatively independent member. Before the saddles can be accorded equal rating with the ring-and side-plate design, actual test data should be submitted to show whether a saddle does in fact act as an integral unit with the branch connection it is intended to reinforce.

The authors are to be commended for the simplicity of the formulas and charts they have prepared. As mentioned above, if these were changed to accord more with the *spirit* of the Boiler Code rules than with the *letter* of the law and if the Code for Pressure Piping formula were substituted where applicable, the formulas would be quite workable.

Fig. 2—10 x 10 In. Schedule 80 Pipe Branch Connection Showing Completed Weld with Ring- and Side-Plate Reinforcement

The question of the adequacy of reinforcing saddles or, for that matter, the ring-and-side-plate design will have to remain a matter of opinion until actual test data are presented. Perhaps the authors have data in their possession which can be offered as supporting evidence of the value of saddles. While the writer has no test data on the revised design of ring reinforcement using side plates he feels they adequately cover the highly stressed areas adjacent to the conventional ring reinforcement and certainly must tend to support these areas, more than would the conventional ring reinforcement, the near adequacy of which has already been demonstrated.**

‡ "Tests of the Resistance to Repeated Pressure of Forged, Riveted, and Welded Boiler Shells," by H. F. Moore, *A. S. M. E. Trans.*, FSP 53-6, 1931.

** "Investigation of Stress Conditions in a Full-Size Welded Branch Connection," by F. L. Everett and Arthur McCutchan, *A. S. M. E. Trans.*, FSP-60-12, Vol. 60, No. 5, July 1938.

THE MODERNIZATION OF A Structural Shop for Welding*

By GEO. F. WOLFE† and PAUL G. STROHL‡

MODERNIZING A STRUCTURAL SHOP FOR WELDING

THE Welding Engineer of one of the large Eastern shipyards was escorting a visitor on a tour of their plant recently and as they came out of one of the buildings made this remark. "Here is the machine shop and away over there," pointing off into the distance, "is the pipe shop; now if we were building a new plant....." But we can't all build new plants so we must make sure that we are doing those things which are necessary to adapt our present equipment to changing conditions.

In common with many other fabricating shops the Neville Island Plant of the Engineering Works Division of Dravo Corporation at Pittsburgh, Pa. had been built up for riveted construction. Then came Welding.

Within a period of less than five years a shop which was riveting 90 per cent of its work is now welding more than 90 per cent. During the first years of the transformation various efforts were made to meet the changing conditions without too much success, so during the past year the decision was made to disregard the old conventions and modernize. This program called for the scrapping of certain obsolete equipment, the relocation of most of the remaining machinery and the purchase of new equipment more suitable for the requirements of welded fabrication.

A general layout of the fabricating shop as shown in Fig. 1 represents conditions which had been developed for riveted construction. All incoming steel was brought in from the storage yard at the left with the flow of work being from left to right through the four aisles and out at the upper end of the Head house. Preliminary operations such as burning and shearing were performed in the Tail house while later operations such as layout, bending, joggling, punching, minor assemblies and preliminary riveting were carried out in the various aisles. Larger assemblies and, final riveting operations were

* Presented at November 15th Meeting, Pittsburgh Section, A.W.S.
† Chairman of Welding Committee.
‡ Engineering Works Division, Dravo Corporation, Pittsburgh, Pa.

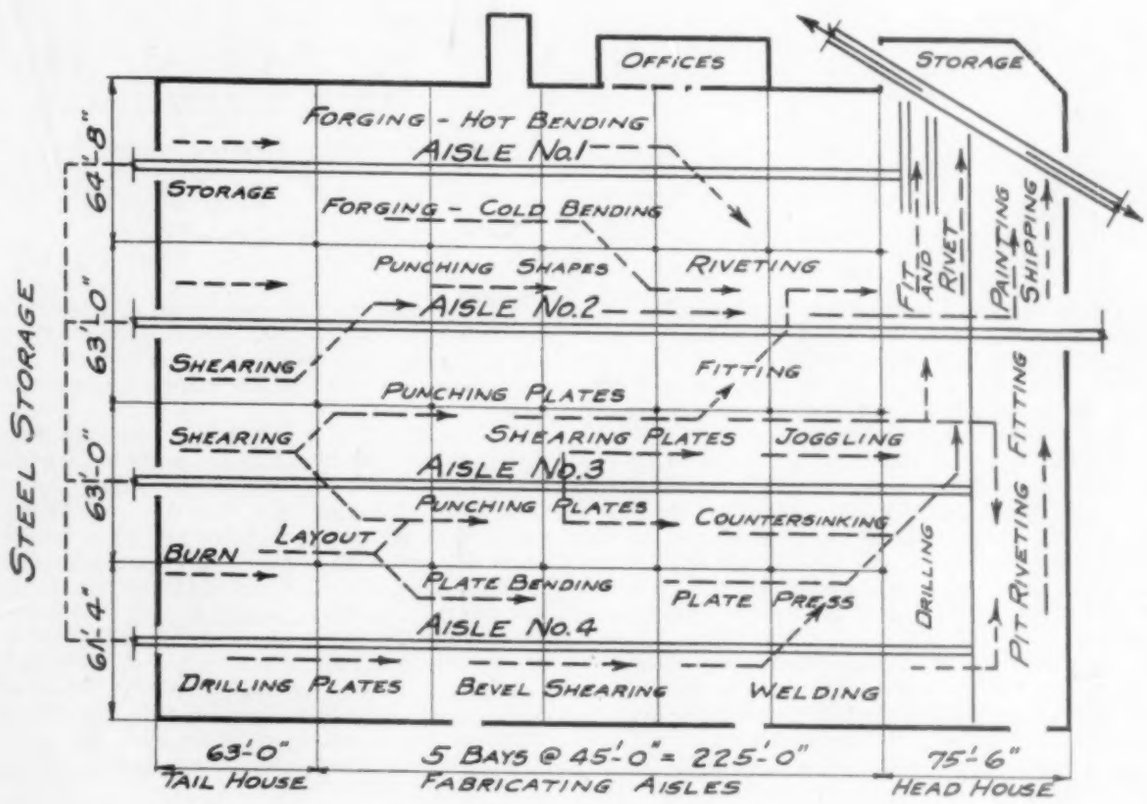


Fig. 1—Original Layout of Shop as Developed for Riveted Construction

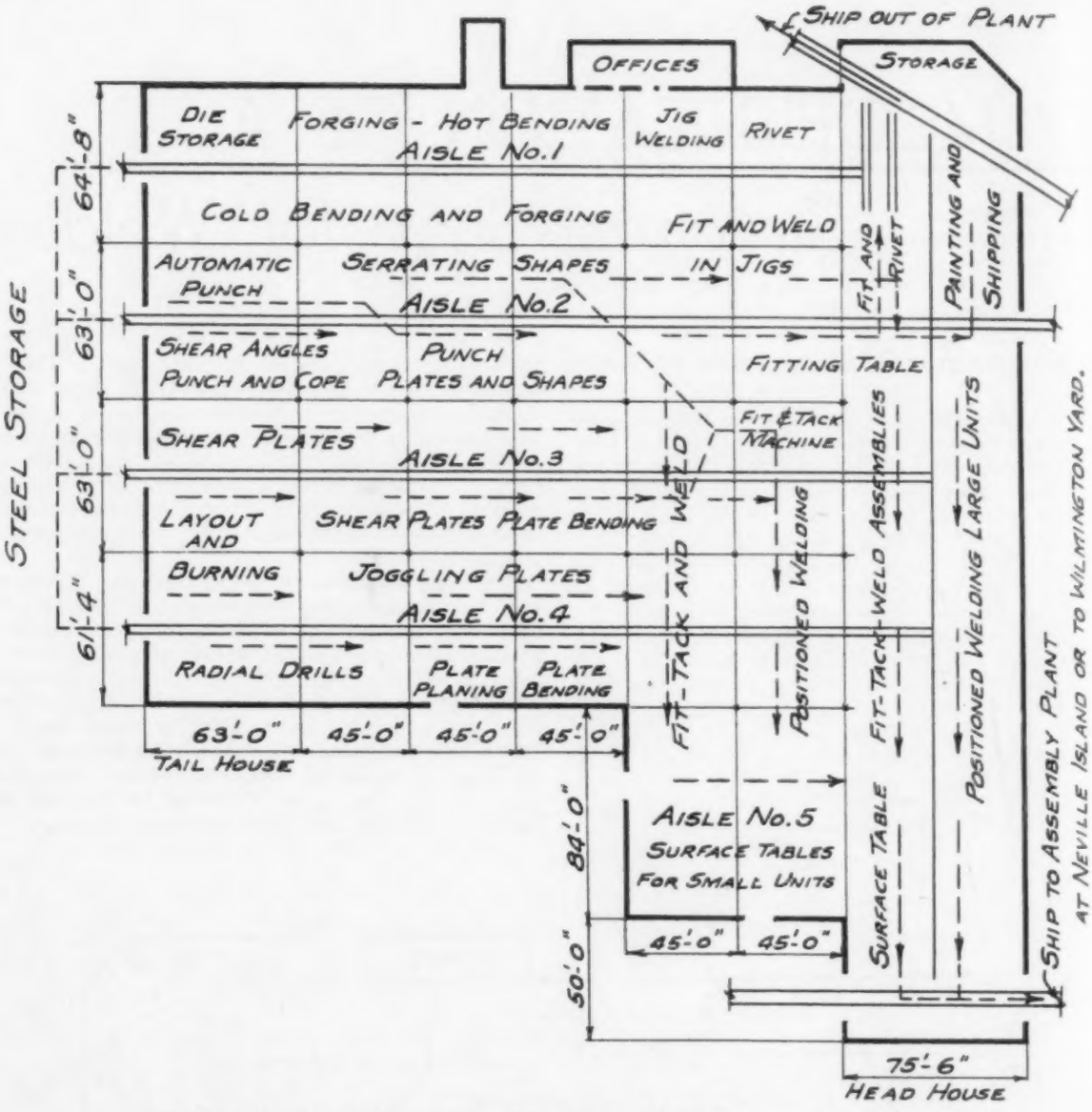


Fig. 2—Revised Layout of Shop After the Addition of Aisle 5 and Lengthening of the Head House

performed in the Head house where shop paint was applied and from which all shipments were made.

The swing over to welding which started slowly in 1934 and 1935 began to upset the usual orderly procedure. With the almost complete change to welding in the next two years operating conditions became more difficult. The space requirements for preliminary operations at the lower end of the shop became less as the necessity for layout and punching operations decreased almost to the vanishing point. At the same time assembly areas in the upper end of the shop became exceedingly congested as this plant has specialized in the production of large welded shop units which require large floor areas.

The answer to the problem presented by these new conditions was too evident to disregard so plans were developed early in 1938 to rearrange such equipment as was applicable to the work contemplated and to put the entire shop on a production line basis where possible.

This program called for the scrapping of some machines such as plate punches, riveting machines and accessories as well as the purchase of new machinery. Even more modern equipment such as a special fit and tack machine was found to be outmoded after but a few years of usage and has been dismantled and rebuilt on an entirely new basis which will be discussed in detail later.

Reference to Fig. 2 will indicate the additions to the shop area which were required in order to keep pace with the rapidly increasing welding program. An entirely new Aisle 5 of larger span than the original aisles was added with an accompanying lengthening of the Head house. New trackage was provided at the extended end of the Head house in order to change the direction of flow for the disposal of large prefabricated units which are taken to the Barge Assembly Plant for final erection or shipped by rail to the assembly yard at Wilmington, Del. With the lengthening of the Head house added crane capacity was provided by the installation of a thirty ton overhead crane which with the twenty ton crane previously in use permits the handling of assemblies up to 50 tons.

In order to present a clear picture of the magnitude of the changes required a detailed layout of the shop

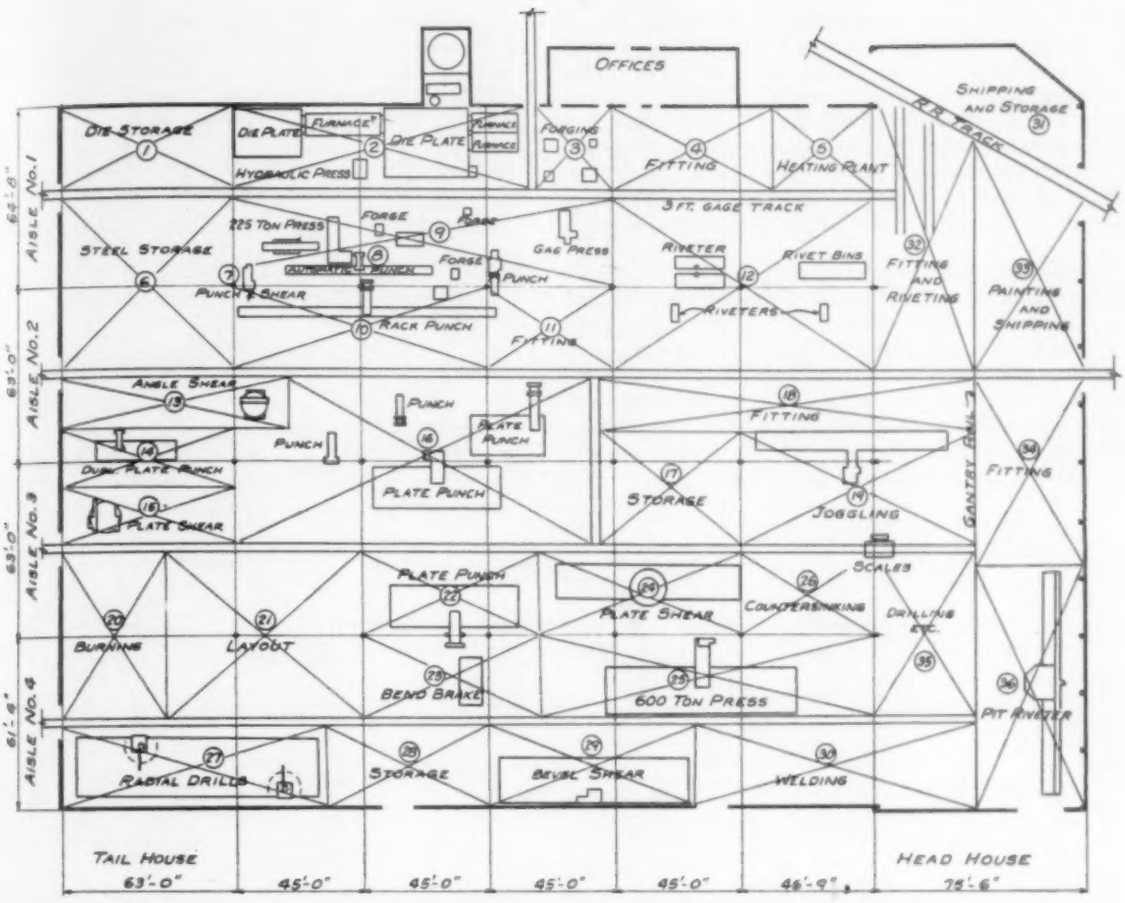


Fig. 3—Detail Layout of Shop as Originally Designed for Riveting

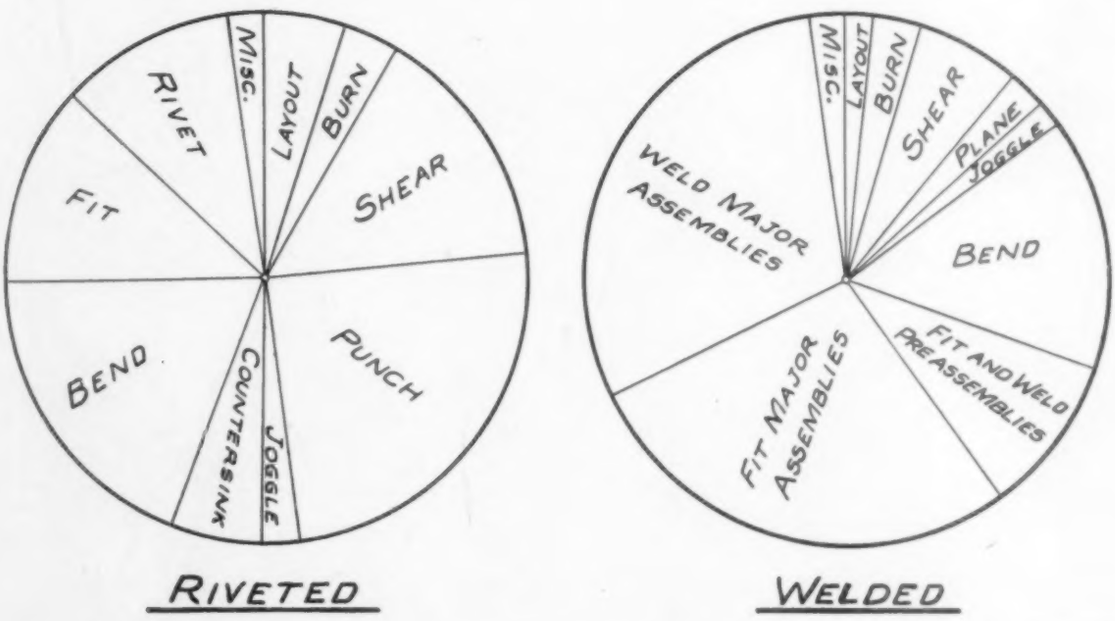


Fig. 4—Comparison of the Cost of Various Operations in the Production of Riveted and Welded Coal Barges. In the Case of the Welded Barge Fitting and Welding, Totalling Almost 70 Per Cent of the Shop Fabrication, Require Large Floor Areas but Reduce Final Erection Time and Expense

machinery and various operations is shown in Fig. 3 which represents the shop as it was in 1929 when a total of 163 all riveted hulls were fabricated. A study of the various areas required for such work as layout, drilling, punching and countersinking will show a large area taken up for these operations with a comparatively small area occupied by the actual final riveting operation. This proportion of areas is due to the fact that in riveted construction very few shop assemblies of great size were made.

In riveted ship work conventional designs were still followed with most vessels having longitudinal plating over transverse framing so that few shop assemblies were possible except for such parts as trusses, rake frames and bulkheads. The same conditions applied to structural fabrication as the difference between the strength of shop and field rivets was not enough to justify large assemblies and the cost factor was often ignored or balanced against the expense of heavier erection equipment.

The transition period between riveting and welding was too brief to permit of a gradual change in plant. The tabulation in Table 1 has been published previously

Table 1—Tabulation of Riveted and Welded Hulls Launched Annually During the Last Ten Years

Year	Riveted Hulls	Welded Hulls	Total Hulls
1929	163	0	163
1930	124	0	124
1931	70	2	72
1932	13	0	13
1933	16	0	16
1934	34	6	40
1935	27	8	35
1936	9	95	104
1937	3	92	95
1938	3	72	75
1939	0	136	136

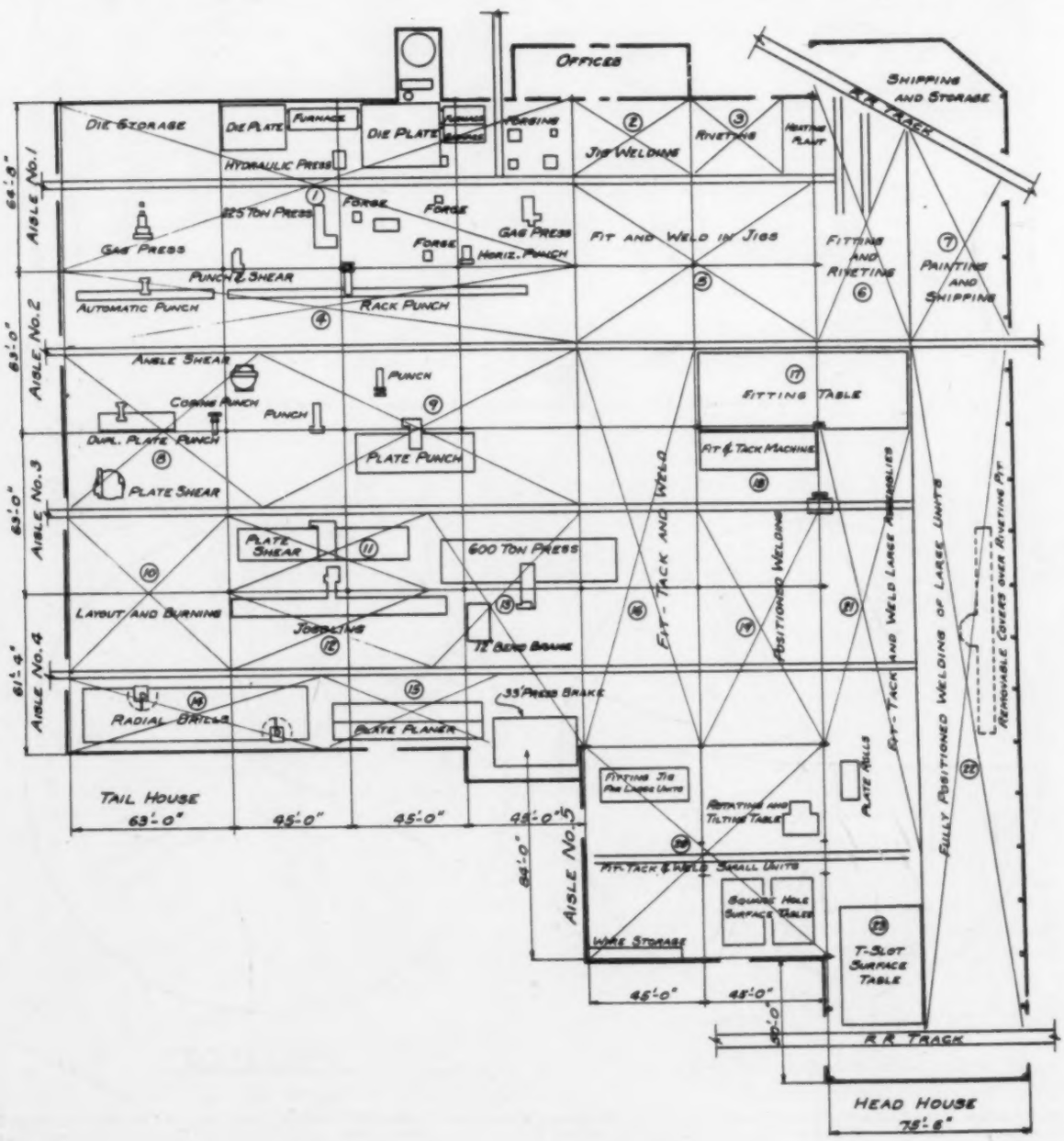


Fig. 5—Detail Layout of the Present Shop Fully Modernized

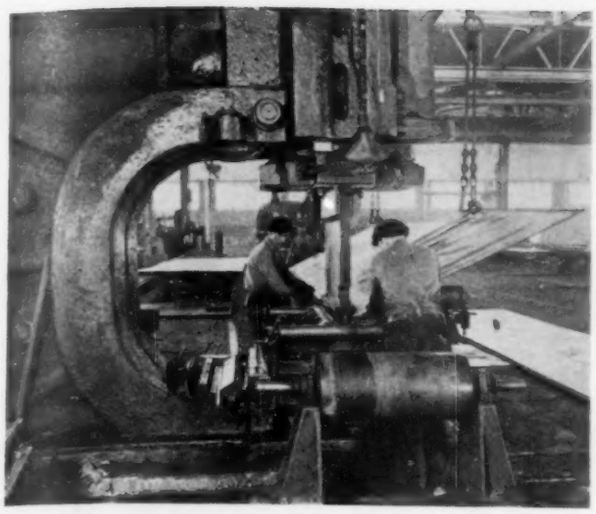


Fig. 6—600-Ton Press Provides for the Bending of Extremely Long Lengths

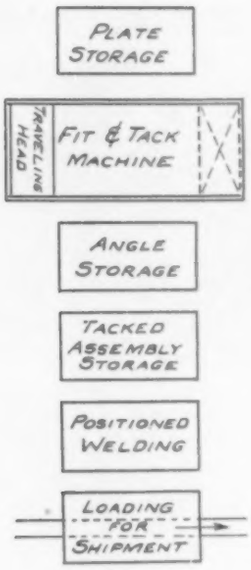


Fig. 7—Straight Line Assembly of Bottom Sections of Barges

but is given here to show more clearly how rapidly the demand for welding grew. Starting in 1934 with six welded hulls out of a total of forty or fifteen per cent of the entire lot the ratio increased in two years to 95 units out of 104 total or 91 per cent welded. For the past two years the percentage of welded hulls has been even greater and has been combined with a correspondingly high percentage of welding on work other than ship construction.

With the influx of welding it was soon found that this type of construction imposed new demands upon both the designers and the shops. In order to secure the maximum of positioned welding, large shop assemblies are predicated and these in turn demand large shop

Fig. 8—Serrated Angle Sections Are Easily Placed in Approximate Position

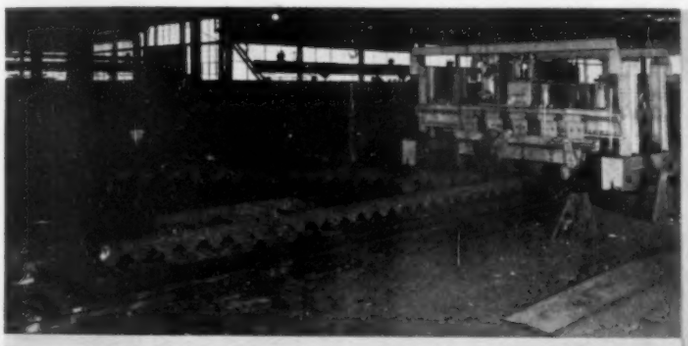


Fig. 9—Traveling Head of Fit and Tack Machine Automatically Spaces Longitudinals and Holds Them Firmly to Plate for Hand Tacking

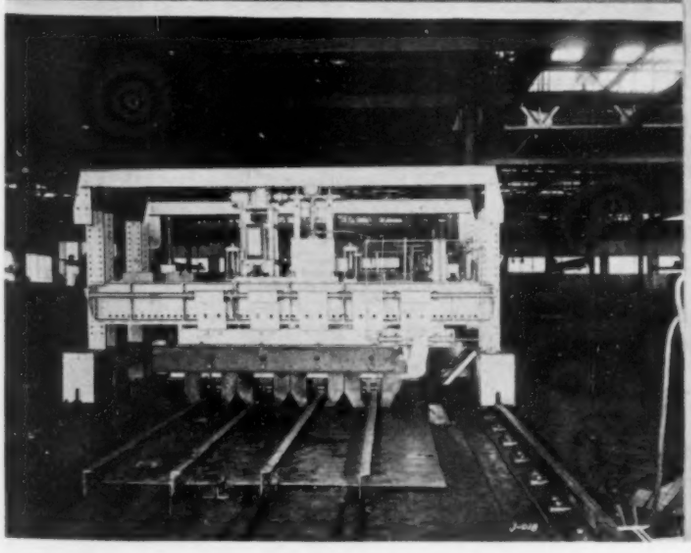


Fig. 10—Storage for Tacked Assemblies Stabilizes Flow on Production Line

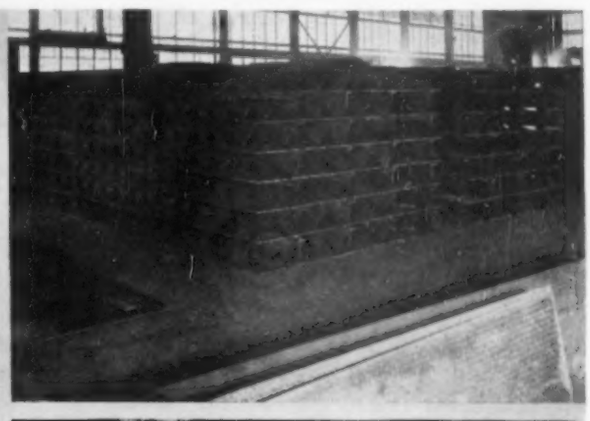


Fig. 11—All Welding Is Fully Positioned for Maximum Strength and Economy

Fig. 12—After Welding Assemblies Go to Barge Shop for Final Erection in Barge

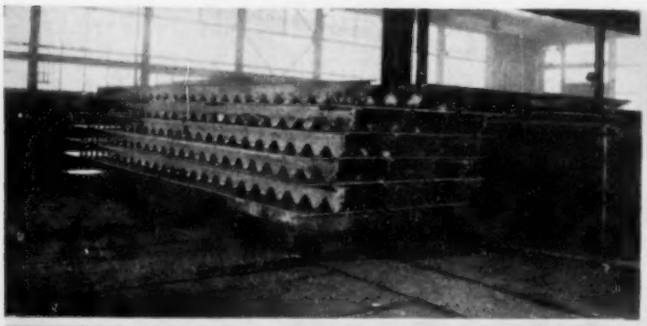
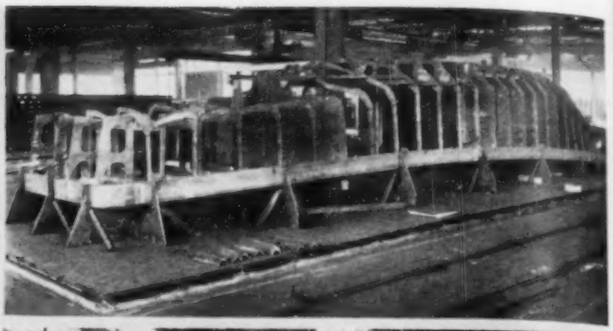


Fig. 14—Steel Floors Facilitate Assembly of 45 Ft. Towboat Hull



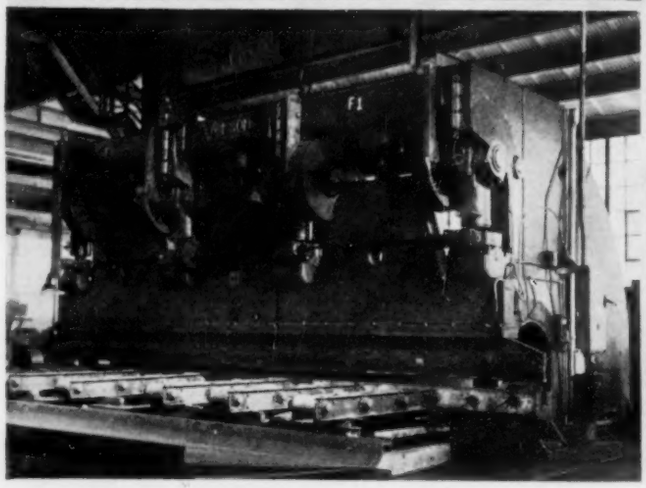


Fig. 13—1000-Ton Press Brake Will Bend Plates as Shown in Foreground with Lengths Up to 33 Feet at One Stroke

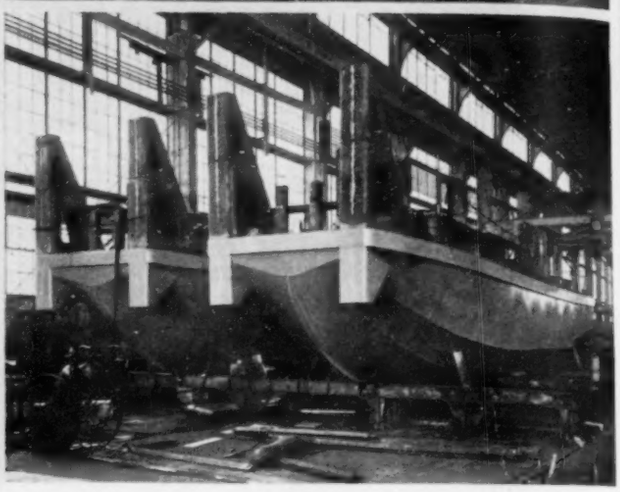


Fig. 15—Former Fitting Skids Now Used for Completing Large Assemblies

areas. The first expedient was to add Aisle No. 5 as shown in Fig. 2 together with an 130 foot extension of the Head house. All of this space was given over to welding but the problem was far from solved. The space was still too small and the flow of material to the assembly areas was hampered by changes in direction of movement as well as the lack of proper equipment for some of the fabrication required. New equipment had been added as the need arose but due to existing machinery had been located in such spots as were available which was not conducive to economical production.

Reference to Fig. 4 will show the effect which the change over to welding has had upon the individual shop operations and which has necessitated radical revisions in the arrangement of shop machinery. Layout time has been greatly reduced; shearing of plates has been lessened due to the ability to use plates in mill widths as minor variations can be taken up in lap joints; bending has been made easier largely due to the placing of the toes of angles against plates which permits angles to be bent the easy way while punching, countersinking and riveting operations have completely disappeared.

Reducing the above operations to percentages it is found that in the case of riveted work prior to fitting up the preliminary steps amount to about 75 per cent of the total shop work while this percentage is only about 30 for welded construction. This large reduction permitted the removal of some of the machinery, particularly punches and countersinking equipment and left more space available for subsequent operations.

In the early part of 1938 the program of relocation of equipment was begun. Figure 5 shows in detail the layout of the present shop. A comparison of the new layout with that shown in Fig. 3 will indicate a general movement of machinery to the left. This move provides greater assembly areas. Of the three plate punches with their large Lysholm tables two have been removed. Most of the smaller riveting machines have been taken out. The large riveting pit in the Head house has been covered over and is kept only for emergencies.

The rack punch, shown in position 10, Fig. 3, originally installed for the multiple punching of shapes has been fitted with special shear blades for the purpose of shearing standard channel sections on a serrated line. The resulting two pieces have the general shape of an angle but have a depth two-thirds that of the original channel and provide a most efficient distribution of material.

Since space at the upper end of the shop was at such a premium even so large a machine as the 600-ton plate press shown in Fig. 6 located at position 25 in Fig. 3 was moved a distance of only about forty feet at the expense of entirely new foundations. The general effect of these removals and changes has been to make available for assembly and finishing operations approximately a 90-foot length of all five aisles as well as the entire Head house.

In addition to the relocation program new equipment has been added consisting of a 35-foot plate planer, a press brake with the capacity to bend plates up to 33 feet in length, numerous positioning tables and large steel and cast-iron floor areas for the accurate fitting of assemblies for welding.

Particular attention has been given to the adoption of straight line assembly methods in order to reduce the handling of material to a minimum. This method of pro-

duction has proved particularly well adapted to the fabrication of bottom sections of the standard coal barge which is almost constantly passing through the shop.

As shown in Fig. 7 plates and serrated angle sections are stored on each side of the Fit and Tack Machine which consists of a steel fitting floor over which is mounted a traveling head. The plate is laid on the steel floor in a position determined by jig plates and the serrated angle longitudinals are dropped into jigged slots for approximate location as shown in Fig. 8. The fitting head, shown in Fig. 9, which is equipped with horizontal adjusting and vertical clamping motions, is then run over the assembly and holds the longitudinals firmly and accurately to the plate for tacking by hand.

The traveling head, which works in either direction of movement, is run off in the clear at either end of the floor and the tacked assemblies are carried over to storage as shown in Fig. 10 and from there on to positioning tables as shown in Fig. 11 where all welding is completed. The finished sections are then loaded directly on buggies, as shown in Fig. 12, for delivery to the Head house for transfer to the Barge Assembly Plant or for rail shipment to the assembly yard at Wilmington, Del.

The Fit and Tack Machine which was shown in Fig. 9 is one of the answers to the demand for proper fitting equipment for welding. Its predecessor was a fixed machine in which the plate was entered over a roller caster bed and in which the serrated angle longitudinals were slid into a series of slots in the cross beams. This machine occupied a considerable area and required twice as much additional area in order to provide space at each end for the entering of the material and the removal of the assembly.

The new type of machine with the material being dropped into position by the overhead crane and with the traveling positioning and clamping head has proved most advantageous and it also lends itself to quick changes in the spacing of members. The development of the improved machine has resulted in the complete scrapping of its predecessor which had seen only a few years of service but this is typical of welding whose progress depends on our willingness to keep pace with its demands.

In common with many other shops it has been found that the best equipment for fabrication in connection with welding is that which permits the elimination of the most welding. This condition is most readily attained by substituting bends for welds and is particularly advantageous in plate work. The recent installation of the press brake, shown in Fig. 13, with a capacity for plates up to 33 feet in length will help to relieve the congestion at the 600-ton plate press. In addition to these two presses other bending such as the bending of beams and rails is carried on in a 225-ton electrically driven bulldozer and a 200-ton vertical four post hydraulic press.

For the final assembly of large sections in the shop it is necessary to provide large plane floors. Several

Fig. 16—Completed Towboat Ready for Immediate Service

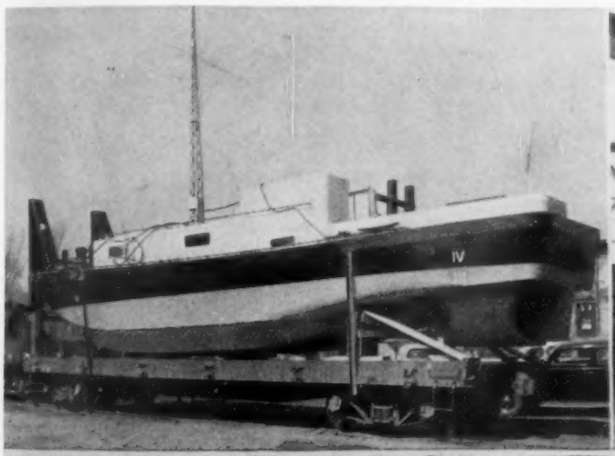
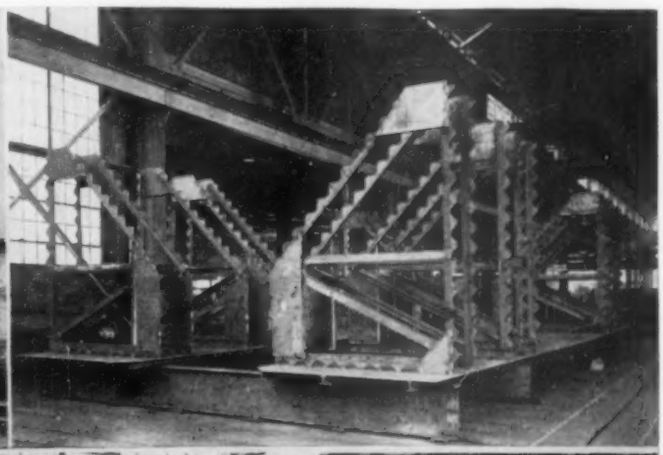


Fig. 18—Start of Large Units Which Reduce Final Erection Time Greatly



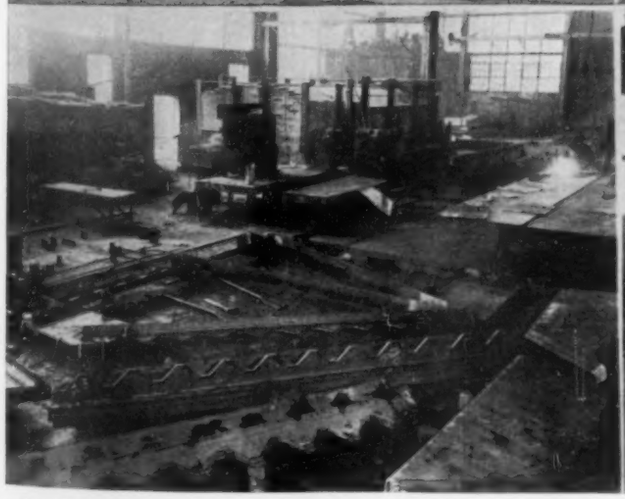


Fig. 17—Many Low Cost Jigs Are Highly Productive in Their Output

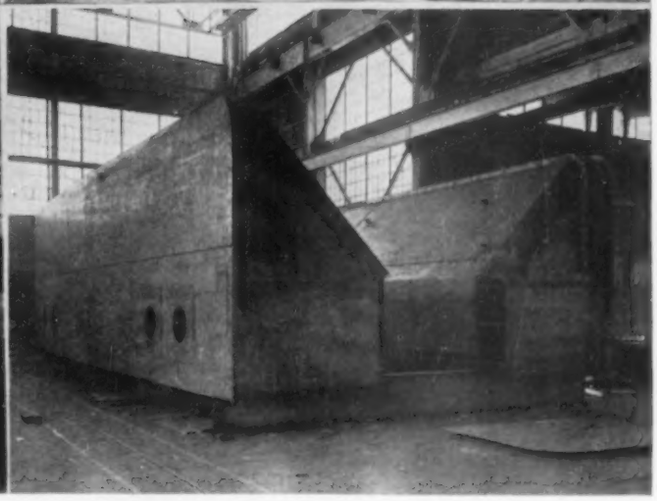
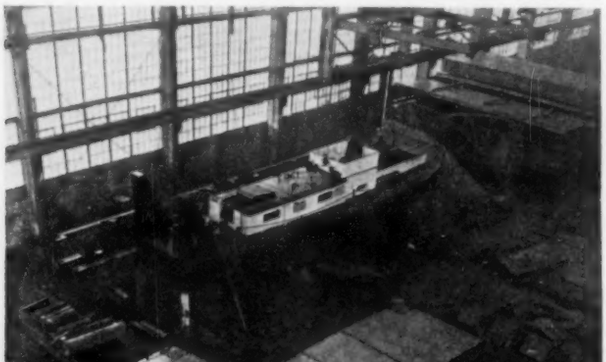


Fig. 19—30-Ton Rake Ends as Shipped by Rail to Wilmington Boat Yard

Fig. 20—Head House Area Is Devoted Entirely to Large Assemblies



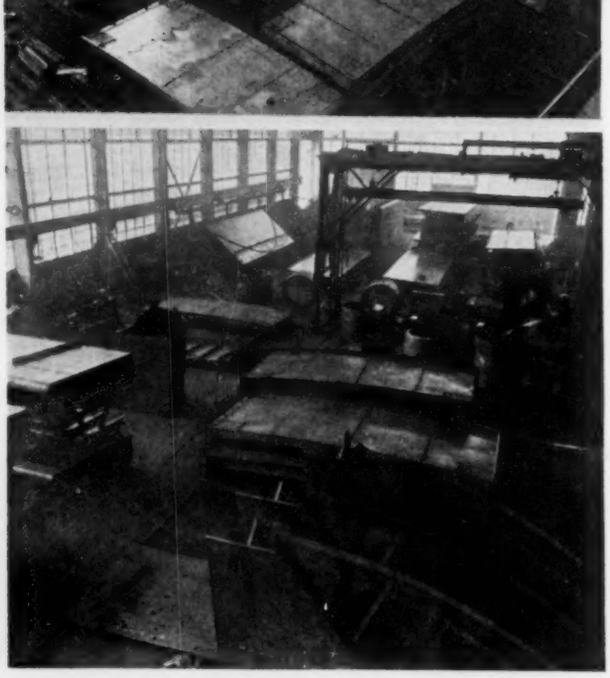


Fig. 21—Large Bulky Units Require Careful Control of Production Schedules

types are used of which one is shown in Fig. 14 with a 45-foot towboat being erected upside down on this floor which is of rolled steel plate with tapped holes at two foot centers for holding down bolts when required. The more usual custom, as shown in the erection of the towboat hull, is to tack assemblies directly to the steel floor or to build up special jigs or forms which are required when erecting irregularly shaped structures such as the towboat illustrated.

When making large shop assemblies such as that shown in Fig. 14 additional large areas are required for the subsequent welding after the assembly is removed from the fitting floor. With such units as the towboat the former fitting skids used for riveting are well adapted for the welded work as shown in Fig. 15. With sufficient floor space available it is possible to keep large assemblies in the shop and carry the work to a much more advanced stage of completion than is usually done. The two towboats in this particular instance, as shown in Fig. 16, left the shop completely outfitted except for the addition of the upper part of the pilot house and when lowered into the river went away under their own power.

In addition to the smooth steel floors two types of cast-iron floors are in use, one with slots for T head bolts while the other has square holes used with dogging bars. In addition to the special steel and cast-iron floors many large jigs are made up by welding spacing lugs to portable steel plates as shown in Fig. 17 where side frames of a small dump scow are being assembled. These frames are then combined into further assemblies as shown in Fig. 18 until a complete box section as shown in Fig. 19 is built up which may weigh from ten to twenty tons or more before it is taken to the point of final erection into the vessel.

The sole purpose of the changes described in this paper was to secure a proper flow of material and room enough for the large assemblies which are necessary to have in order to get all of the benefits which accompany welding. Figures 20 and 21 show a typical concentration of work being assembled in the Head house or waiting for shipment. An equally large space has been made available in the adjacent aisles and needless to say the efficiency of this shop is keeping pace with these improvements.

Welding is certainly here to stay and the end of riveting except for some building work and long bridge spans is definitely in sight. Welding equipment and personnel have shown a very wonderful development but in order to realize all of the benefits and economies of welding the fabricators are now facing major expenditures.

The changes as shown and discussed in this paper were made only after careful studies of the results to be gained and the costs involved. It was felt, however, that these changes were not only desirable but were absolutely necessary in order to place welding on a proper productive and economical basis.

WELDING METALLURGY

By O. H. HENRY and G. E. CLAUSSEN

A series of lectures prepared for presentation in a fundamental course of metallurgy and metallography at Polytechnic Institute of Brooklyn under the joint auspices of the Institute and the New York Section of the AMERICAN WELDING SOCIETY. To be published serially in The Welding Journal. Available in Pamphlet Form—47 pages Journal Size. Copiously Illustrated at $1.00 per copy. Special Prices quantity lots ten or more.

Part II—Types of Steels and Their Manufacture

Iron Ore (Fe_2O_3 + impurities; 50% iron)
↓ blast furnace
Pig Iron (4% C, 1.7 Mn, 1.0 Si, 0.25 P, 0.04 S)
↓ open hearth
Steel Ingot
↓ rolling mill
Steel plate, sheet, or section

The flow sheet shows that iron ore passes through the pig iron and ingot stages before appearing in commercial form.

Iron Ore—iron oxide (ferric oxide = Fe_2O_3) containing moisture and other impurities (aluminum oxide, silicon oxide, phosphorus pentoxide) and known as HEMATITE, mined principally in Michigan. A small amount of MAGNETITE (magnetic iron oxide = Fe_3O_4) is mined in New York and Pennsylvania.

Blast Furnace

About 20 feet in diameter, 90 feet high, lined with refractory bricks, converts about 700 tons of iron ore to pig iron per day.

Materials Charged in Blast Furnace

At top of furnace: iron ore (4000 lb. per ton of pig iron produced); limestone ($CaCO_3$ = calcium carbonate) (1500 lb. per ton of pig iron); coke (90% fixed carbon, remainder ash and moisture; made by distillation of coking grades of soft coal) (1700 lb. per ton of pig iron produced).

At bottom: air (25% oxygen, 75% nitrogen) at 1300° F. and 15 lb./sq. in. gage pressure (10,000 lb. per ton of pig iron produced).

Materials Discharged from Blast Furnace

At bottom of furnace: pig iron (13%); slag (10%) mainly calcium aluminum magnesium silicates.

At top: gas (75%) mainly nitrogen and carbon monoxide; flue dust (2%) mainly iron oxide and carbon.

Operation—as ore descends it is heated by the hot blast. About midway down the furnace the ore reacts with coke at about 900° C. to form iron and carbon monoxide. The CO goes out the top of the furnace, while the iron descends further, is melted by combustion of the remaining coke, and forms pig iron containing 4% carbon which is tapped from the furnace at intervals. The molten pig iron is carried to the open-hearth furnace.

Open-Hearth Furnace

About 40 million tons of steel is produced in open-hearth furnaces Fig. 1, in this country in a good year. The open hearth is a refractory hearth or pan about 15 ft. wide, 45 ft. long, 3 ft. deep for a furnace producing 150 tons of steel in about 11 hours. In contrast with the blast furnace which is a continuous furnace, the open hearth is a batch furnace.

Materials charged in Open Hearth: scrap (40%); molten pig iron (50%); limestone (10%).

The scrap is partially melted by means of a reducing natural gas flame (other fuels may be used) before the molten pig iron from the blast furnace is poured in. The resulting mass consists of liquid metal 30 inches deep containing about 2% carbon upon which floats a slag 6 inches deep. The bath of molten metal and slag is open to the gases passing over it, whence the name open hearth. In order to remove the carbon from the metal, iron ore and limestone are added periodically, until after several hours the carbon content, together with the Mn, S and P contents, have been driven low enough.

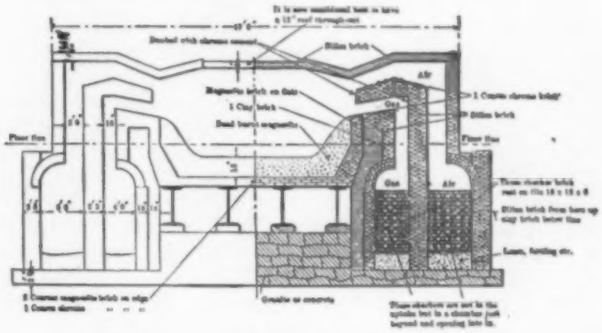


Fig. 1—An Open-Hearth Furnace (Stoughton)

The resulting molten steel is saturated with iron oxide, which has been the reagent that removed the carbon in the earlier stages of refining. There are two ways of dealing with the iron oxide:

1. *Killed Steel.*—Silicon is added to react with iron oxide, which is soluble in molten iron, to form silicon oxide (silica) or silicates, which are solid and insoluble in molten iron and rise from the steel to the slag. After the silicates have risen to the slag the oxygen-free steel is tapped from the bottom of the furnace into a ladle, thence into ingot molds.

2. *Rimmed Steel.*—Manganese is added as ferromanganese to react with some of the iron oxide. Unlike the oxides of silicon, the combined oxide of manganese and iron is fluid in the molten steel. After the steel has been tapped into the ladle and ingot mold, it commences to solidify by depositing a crust of nearly pure iron about 3 inches thick on the walls of the ingot mold. As a result the remaining liquid steel has a higher carbon content and reacts with the fluid iron-manganese oxide to form carbon monoxide, a gas. Some of the gas bubbles rise to the top of the ingot. The remainder are trapped in the lower portions of the ingot and equalize the shrinkage of the steel during solidification. Consequently, ingots of rimmed steel do not have the deep shrinkage cavities, known as pipe, which are characteristic of some killed steel ingots.

Comparison of Killed with Rimmed Steels

	Killed Steel	Rimmed Steel
Carbon Content	0.15–0.25% and over (sometimes steels with 0.15–0.25% are semi-killed)	0.15% or less
Silicon Content	0.15% or over	Less than 0.05%
Manganese Content	0.30% or over	About 0.40%
Piping (shrinkage)	Severe	None
Segregation	Little	Pronounced

Low-carbon steel sheets and plates, which represent the greatest item in steel production, are made of rimming steel. During subsequent rolling, the blow-holes weld together and disappear, but the pronounced segregation remains in the finished plate or sheet. The plate or sheet consists of a surface of nearly pure iron beneath which is steel containing higher sulphur and carbon.

Hence, the term "segregated" is applied to rimming steel. If segregation is excessive, welding qualities may be sacrificed.

The higher-strength and higher-carbon structural and forging steels (silicon, that is, killed steel) are killed, because the rimming reaction cannot be made to occur above about 0.15 C. The reason is that the high initial carbon content of the steel prevents the solution of sufficient oxygen, with which the carbon reacts. Since alloying elements often spoil the rimming reaction, low-carbon alloy steels generally are killed or semi-killed. The term "killed" denotes that the steel remains perfectly quiet while it solidifies in the ingot mold, contrary to the bubbling (effervescence) that characterizes the solidification of rimming steel. If it were attempted to kill the low-carbon steels in the furnace at the right temperature at which they must be refined, the silica would attack the magnesia lining of the hearth, whose life would be seriously shortened, and the resulting slag would contaminate the steel.

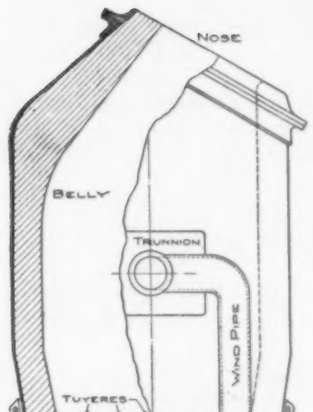


Fig. 2—A Bessemer Converter (Hayward)

Acid—Basic

The foregoing description applies to the basic open-hearth furnace. A basic furnace is lined with a basic material (magnesia), which is not attacked by a basic slag (40% lime CaO, 25% SiO_2, 15% manganese oxide MnO, 8% FeO, 7% magnesium oxide MgO). A basic slag reacts with acid components in the steel to form compounds which remain in the slag. The principal acid components that are removed from the metal in the basic open-hearth process are phosphorus and silicon.

It is possible to line the open hearth with an acid material (sand = silica) and to use an acid slag (60% SiO_2, 20% MnO, 20% FeO), but the acid open-hearth process is limited to a small tonnage of exceptionally high-grade medium carbon steels.

Bessemer Process

Instead of the open-hearth process the Bessemer process can be used to convert pig iron to steel. About 10% of all the steel produced is Bessemer steel. Most of the Bessemer steel is pipe skelp, free-machining or tin plate steel, which seldom requires fusion welding in its fabrication. Bessemer steel is characterized by excellent forge-welding properties, and is equal to open-hearth steel for fusion welding.

Bessemer Converter, Fig. 2—a tilting vessel (10–25 tons capacity) about 9 ft. in diameter, 12 ft. high, lined with siliceous material (acid process) and having a perforated bottom, the holes being about $^3/_4$ inch in diameter. While the converter is on its side, pig iron is poured in. As the converter is righted a blast of air (not heated) at 20 lb./sq. in. is blown through the holes and molten steel. The oxygen in the air reacts first with the silicon and manganese, removing them to the slag (iron-manganese silicate), which floats on the metal. Then the carbon is oxidized as carbon monoxide which burns to CO_2 in a long blue flame at the top of the converter. The combustion of Si, Mn and C raises the temperature of the metal in the converter. Just as the carbon flame dies out, which is 12 to 18 minutes after the process began, the operator tilts the converter and pours the steel into a ladle, thence into ingot molds.

Bessemer steel is characterized by high phosphorus content, up to 0.11%, and usually contains up to at least 0.07% sulphur.

Other Steel Making Processes

Basic Electric Process.—Used for tool and other high-grade, medium- and high-carbon and alloy steels. The furnace is lined with magnesite ($MgCO_3$) and heat is supplied by arcs between three carbon electrodes and the molten metal. Capacities up to 100 tons. The charge consists of steel. The product generally is exceptionally low in sulphur and phosphorus, for example, 0.005 S, 0.005 P.

Acid Electric Process.—Used for steel castings. An arc furnace similar to, but usually much smaller than, the basic electric furnace is used, but is lined with ganister (silica = SiO_2). The charge consists of selected steel.

High Frequency (or Coreless Induction) Process.—Used for stainless steel and special tool steels. The furnace consists of a coil (for example 40 turns, 12 inches diameter, 2 ft. high) of water-cooled copper tubing, which acts as the primary of an air transformer. The secondary is the metal to be melted which is contained in a magnesite lining inside the copper coil. A high-frequency current (1000 cycles, 300 kw. for a charge of $^1/_2$ ton) passes through the coil which induces similar high frequency currents in the outer portions of the charge, which consists of chunks of metal whose size and shape is governed by the dimensions of the furnace. The heat from the outer parts of the charge is conducted to the center and the charge usually melts within 1 hour. On account of the strong stirring action created by the high frequency current, only a few minutes are required for refining after which the steel is poured into ingots or castings. There is no carbon pick-up.

Ingots

If molten steel from any of the steel furnaces were to be cast into molds having the shape of the desired product, we would always be dealing with cast steel in our engineering structures. Since cast steel is generally inferior to wrought steel, the molten steel is cast into large blocks, called ingots. The molds into which the steel is poured from the bottom of the ladle are about 7 ft. high and 6 inches thick.

Blooming Ingots—nearly square (25 x 30 inches, ingot weight 1500 lb.) for rods and structural sections.

Slab Ingots—rectangular (25 x 55 inches, ingot weight 2500 lb.) for plates and sheets.

The walls of the mold are corrugated or fluted to promote soundness in the ingot. In order that the ingot may be stripped (removed) readily from the mold after solidification, which occupies about an hour, the top may be smaller (small end up) or larger (big end up) than the bottom. Rimmed steels are cast in small-end-up molds; killed steels in big-end-up. The latter sometimes are fitted with hot tops to maintain molten metal to feed the shrinkage cavity.

After the ingot has solidified, it is stripped from its mold and is placed in a furnace (soaking pit) in which its temperature is equalized and is suitable for rolling.

Rolling

From the soaking pit, blooming ingots go to a blooming mill; slab ingots to a slabbing mill. The blooming mill consists of two large rolls which reduce the ingots to a "bloom" about 9 inches square in about 25 passes through the rolls. Slabbing mills have a similar purpose, but the resulting slabs are about 4 x 30 inches.

Blooms go through a continuous semi-finishing mill consisting of 10 or 12 pairs of rolls, and then either through a structural mill, if the desired product is a structural section (column, I beam, angle, etc.), or through a bar mill, both bar and slab mills consisting of a number of pairs of suitably grooved rolls which by stages transform the rudimentary billet, 5 inches square, into the finished product.

Slabs go through a plate mill, which may consist of three rolls, one above the other. The plate passes first through the lower pair of rolls; it is then returned through the upper pair. Reversing two high mills (single pair of rolls) also are used. Vertical rolls are provided with both mills to control the width of the plate.

After being rolled, the steel is cooled on racks to prevent distortion. Rolling converts the cast grain structure into a wrought structure (smaller grains without blow-holes) but does not eliminate segregation. In the rolling mills about 25% of the weight of the original ingot is lost through shearing off ingot tops and billet ends, and through scaling (oxidation of the surface of the steel).

Types of Steels

Classified according to method of manufacture: basic open hearth (90% of steel output); rimming 0.15% C and less; semi-killed 0.15–0.25% C; killed 0.25% C and over.

Armco iron (0.02% C, commercially pure iron)
Acid open hearth (high-grade forging steel)
Bessemer (skelp, screw stock, tin plate)
Basic electric (tool and alloy steels)
Acid electric (steel castings)
High-frequency (stainless steels)
Aston process (wrought iron, which contains 0.03% C, 3% slag)

Classified according to carbon content (plain carbon steels)

0.02% C Armco ingot iron
0.06–0.25% C low carbon or mild steel
0.25–0.50% C forging (medium carbon) steels (axles)
Above 0.50% C spring and tool steels (high-carbon)

Classified according to alloying elements. (S. A. E. Classification. The last two numbers indicate the carbon content)

10xx unalloyed (plain-carbon); for example, S. A. E. 1020 contains 0.20% C (0.15–0.25% C)
11xx free cutting steel (0.075–0.30% S)
2xxx nickel steels; for example S. A. E. 2330 is a steel containing 3 1/2% Ni, 0.30% C
3xxx nickel-chromium steels
4xxx molybdenum steels
5xxx chromium steels
6xxx chromium-vanadium steels
7xxx tungsten steels (tool steels)
9xxx silicon-manganese steels (leaf springs)

The S. A. E. classification is intended for automotive purposes. Structural and tank steels, for example, ordinarily would not be ordered to S. A. E. specifications.

Classified according to A. S. T. M. specifications (the following steels are suitable for fusion welding).

A 7. Steel for Bridges and Buildings

Tensile strength = 60,000 to 72,000 lb./sq. in.
Yield strength = at least 1/2 tensile strength.
Elongation in 2 inches, min. = 22%

The following requirements are placed on the chemical composition of the steel:

Phosphorus, max., per cent	
Open-hearth or electric furnace	
Acid	0.06
Basic	0.04
Acid-Bessemer	0.10
Sulphur, max., per cent	
Open-hearth or electric furnace	0.05

Steel for plates and sections 7/16 inch in thickness, intended for use in buildings and other structures subject to static load only, may be made by the acid-Bessemer process.

NOTE: The carbon and manganese contents are not specified in A 7. The 1938 specifications for Welded Highway and Railway Bridges of AMERICAN WELDING SOCIETY restrict the composition of the base metal to not over 0.25 C and 1.00 Mn.

A 10. Mild Steel Plates (for general plate construction)

Tensile strength = 55,000 to 65,000 lb./sq. in.
Elongation in 2 inches, min. = 24%

The only requirements for chemical composition are:

Phosphorus, max., per cent	
Acid	0.06
Basic	0.04
Sulphur, max., per cent	0.05

A 70. Flange and Fire-Box Steel (Carbon-Steel Plates for Stationary Boilers and Other Pressure Vessels)

	Flange	Fire-Box
Carbon, max., per cent		
For plates 3/4 in. and under in thickness	.....	0.25
For plates over 3/4 in. incl., in thickness	.....	0.30
Manganese, max., per cent	0.80	0.80
Phosphorus, max., per cent		
Acid	0.05	0.04
Basic	0.04	0.035
Sulphur, max., per cent	0.05	0.04
Tensile strength, lb./in.²	55,000 to 65,000	55,000 to 65,000
Yield strength, min., lb./sq. in.	0.5 Tens. Str.	0.5 Tens. Str.
Elongation in 2 in. min., per cent	1,700,000 / Tens. Str.	1,750,000 / Tens. Str.

A 149. High-Tensile Strength Carbon-Silicon-Steel Plates for Pressure Vessels

The steel is made in open-hearth or electric furnaces and must conform to the following requirements:

	Grade A	Grade B
Tensile strength, lb./in.²	65,000 to 77,000	70,000 to 82,000
Yield point, min., lb./in.²	0.5 Tens. Str.	0.5 Tens. Str.
Elongation in 8 in., min., per cent:		
Flange	1,550,000 / Tens. Str.	1,550,000 / Tens. Str.
Fire-box	1,600,000 / Tens. Str.	1,600,000 / Tens. Str.

	1,750,000 Tens. Str.	1,750,000 Tens. Str.
Elongation in 2 in., min., per cent		
Carbon, max., per cent:		
For plates 1 in. and under in thickness	0.28	0.31
For plates over 1 to 2 in., incl., in thickness	0.31	0.33
For plates over 2 to 4½ in., incl., in thickness	0.33	0.35
Manganese, max., per cent	0.90	0.90
Phosphorus, max., per cent:		
Flange	0.04	0.04
Fire-box	0.035	0.035
Sulphur, max., per cent:		
Flange	0.05	0.05
Fire-box	0.04	0.04
Silicon, per cent	0.15 to 0.30	0.15 to 0.30

The maximum thickness of flange quality plates shall be 2 inches and for ordinary fire-box quality plates, 4½ inches.

Fire-box plates over 2 inches thick are uniformly heat treated to produce grain refinement.

Principal High-Alloy Corrosion-Resisting Steels

4–6% Cr, 0.10% C, 0.5% Mo = oil still tubes (usually welded)

11–13% Cr, 0.10% C = martensitic stainless iron (rarely welded)
12–14% Cr, 0.25–1.0% C = cutlery stainless steel (rarely welded)
16–18% Cr, 0.12% C max. = ferritic stainless iron (for arc and gas welding applications)
18% Cr, 8% Ni, 0.12% C max. = 18–8 austenitic stainless steel (excellent for arc, gas and resistance welding). Frequently 0.4–1.0 titanium or columbium is added to plate and filler rod. Practically non-magnetic, hence very little arc blow in D.C. arc welding.

Questions

1. The majority of steel that is fusion welded is made by what process?
2. What are the differences between rimmed and killed steel?
3. What are the rôles played by carbon and oxygen in the blast furnace? in the Bessemer converter?
4. Why is wrought steel used wherever possible in preference to cast steel?
5. What is the maximum tensile strength advisable for steel for welded bridges and buildings?

NOTES REGARDING SPECTROGRAPHIC and X-Ray Tests of Metals Used in Modern Industrial Welding Practice*

By WILLI M. COHN†

SPECTROGRAPHIC ANALYSIS

LET us pass a beam of light through a prism or a grating. What happens? The light is broken up into a number of colors. A light bulb with a hot filament gives off "white" light. Upon spectral analysis we find that this light includes all the colors of the rainbow in it, from blue to red. This is a continuous spectrum. A mercury arc shows, upon analysis with the spectrograph, a few well-defined colors only, such as green, blue and violet. This is a discontinuous or line spectrum.

Each element shows when volatilized in a flame, an electric arc, or a spark, a line spectrum characteristic of that particular element. The number of lines of each element varies. Fe, for instance, shows a large number of lines extending from the ultra-violet to the infra-red parts of the spectrum, whereas sodium shows only a few lines, the most characteristic ones in the yellow.

There are some other methods of exciting line spectra of the elements such as the gas discharge, the electric furnace, exploding wires, etc.; but the flame, the arc and the spark are used in most industrial tests. We take a small amount of the metal to be tested (often just a few milligrams) and hold it into a flame or place the metal on one electrode of the arc or spark. We may also make a solution and bring it into the flame, arc or spark. We observe the spectrum visually or photograph it. We measure the position and relative intensity of the lines and compare the data with standards obtained from pure elements. The position of the lines in the spectrum tells us qualitatively which elements are present and the intensity of the lines gives us quantitative data regarding the amount of elements present.

The accuracy of spectrographic tests is quite surprising. According to Vincent and Sawyer the following percentages may be read simultaneously from a single spectrum: Cr, 0.01 per cent to 1.50 per cent; Cu, 0.20 per cent to

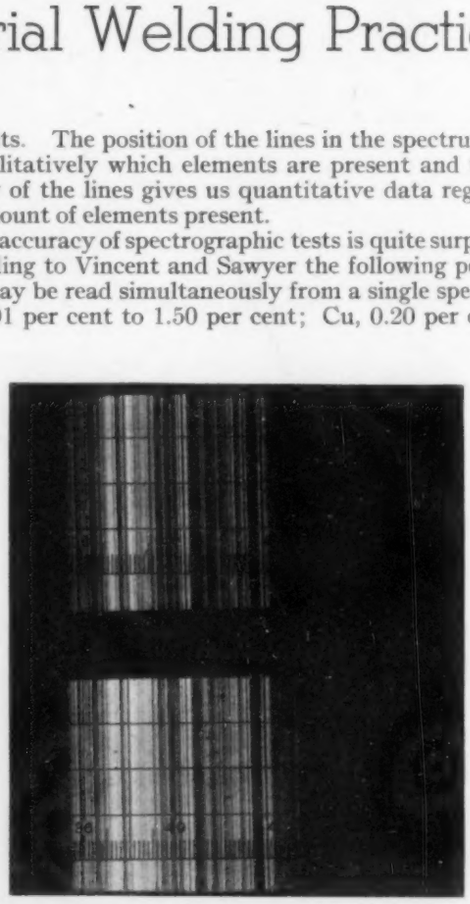


Fig. 1—Iron Spectra in the Visible Region; Hilger Grating Spectrograph with Small Dispersion; Various Details Brought Out by Varying the Time of Exposure

* Presented before the Joint Meeting at San Francisco of the AMERICAN WELDING SOCIETY and the American Society for Metals, Golden Gate Chapter, April 17, 1939.

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Fig. 2—X-ray Diffraction Pattern of Powdered Quartz

3.00 per cent; Mn, 0.30 per cent to 1.25 per cent; Mo, 0.07 per cent to 1.50 per cent; Ni, 0.15 per cent to 2.00 per cent; Si, 0.50 per cent to 4.00 per cent. The average accuracy is such that ±5 per cent of the amount of an element present in a metal may be determined. In many cases, for instance in the plant, less accuracy is necessary and the tests are simplified accordingly.

I have been asked many times, just how much does it cost to install spectrographic equipment? Well, this is rather a difficult question. Let me tell you a story. I built a house recently and kept looking over the advertisements of kitchen ranges. I could hardly find a range advertised for less than $110.00. Finally I went into a store myself and looked around, telling the salesman that I did not want all the latest gadgets, all the lady or I want to do is to cook and fry and broil. I was much surprised that I really did find an excellent, new range at just one-half of the price in the advertisements. Exactly the same is true for spectrographic equipment. You will find advertised all sorts of fancy instruments costing between $1500 and $3000. But very often you can do the same or even better work with small instruments. It is often better to make with a small instrument a sharp and rapid photograph which will stand a considerable enlargement than to use a large instrument which causes long exposure, difficult focusing and difficult handling of the plates in sensitizing and developing.

Another question: Should one use glass or quartz in the optical parts of the instrument? This depends entirely on whether or not one must do much work in the ultra-violet part of the spectrum. In most cases, this is *not* the case and I find it by far easier to work with glass optics which may be used from about 3000 Å in the violet to 10,000 Å and more in the infra-red. Glass optics further permit the visual measurement of lines which is entirely sufficient for some tests.

Finally: Prism spectrograph or grating? Here are two main points to be considered: (1) The prism spreads out the blue and ultra-violet parts of the spectrum and condenses the red. The dispersion in the violet often amounts to 20 times that in the red. The grating gives the same dispersion over the entire spectrum. (2) Times of exposure are shorter for a prism than for a grating of comparable dispersion. From my experience I prefer the grating in work with metals because of the uniform dispersion and because the time of exposure will seldom amount to more than a few seconds.

This brief survey suggests already some applications of the spectrograph in the laboratory and in the plant: If we want a very rapid and inexpensive method of controlling production, for instance in a foundry or in an open-hearth plant, we will use the spectrograph. An approximate analysis obtained within ten or fifteen minutes after taking the sample is often more important in the plant than a chemical analysis a day or several days later. If we want to determine the presence of small amounts of minor constituents in a steel, a welding electrode or a welding flux, we will use the spectrograph. If the chemist wants to avoid a long and laborious analysis he will ask us what to look for in a given alloy. We will make a test with the spectrograph and give him the answer. However, the spectrograph is not designed to replace the chemical analysis. All it does is to supplement it and to make the work of the chemist in some cases easier and, sometimes, faster. (I purposely say "sometimes" because many chemical and colorimetric determinations are carried out so rapidly that the spectrograph offers no advantage.) On the other hand, it is no particular fun for the chemist to determine the amount of Sn or Zn in 99.9% pig lead or the amounts of chromium and molybdenum in stainless steel, whereas such data can be obtained without much difficulty by the spectrograph.

There are many other uses of the spectrograph, such as checking up on the raw materials, sorting of scrap, etc. If an instrument is once available in your plant you will be surprised how many different uses turn up (see also the literature cited).

There is a method of semi-spectral analysis available which I want to mention here: If we are looking just for one or two impurities in a material otherwise constant in composition we may replace the prism or grating by a color filter and the photographic plate by a photoelectric cell. Then we hold our material to be tested into the flame, etc. For instance, we read directly on a meter, the percentage of potassium in a given sample. This method is very practical in some cases but it cannot be used where the composition of the materials varies considerably.

X-RAY ANALYSIS

Most of us are familiar, from some sad experience, with the doctor's order: "Have an X-ray made of this broken arm." What happens next is this: The arm of the poor fellow is clamped down on a support, a photographic film is placed under the arm and an X-ray tube over the arm. The X-ray tube is turned on, the film is developed and we see in this so-called radiograph or shadowgraph the bones inside of the arm.

We do just the same with metals, such as castings and welded parts. The only difference is that we use higher energies than in medical work to obtain our X-ray pictures. What do these pictures show? We find out how

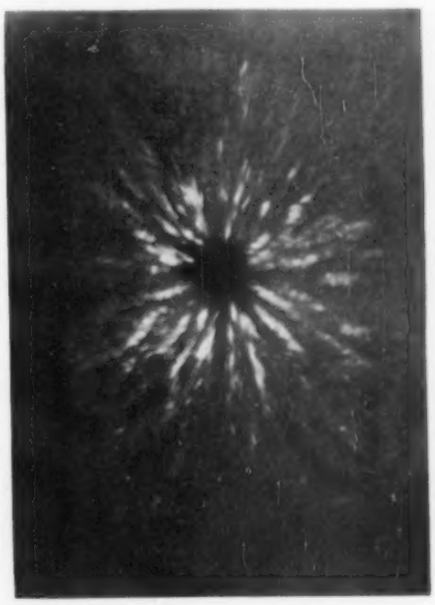

Fig. 3—Diffraction Pattern of Sodium Chloride of Large Grain Size and Under Considerable Internal Strain

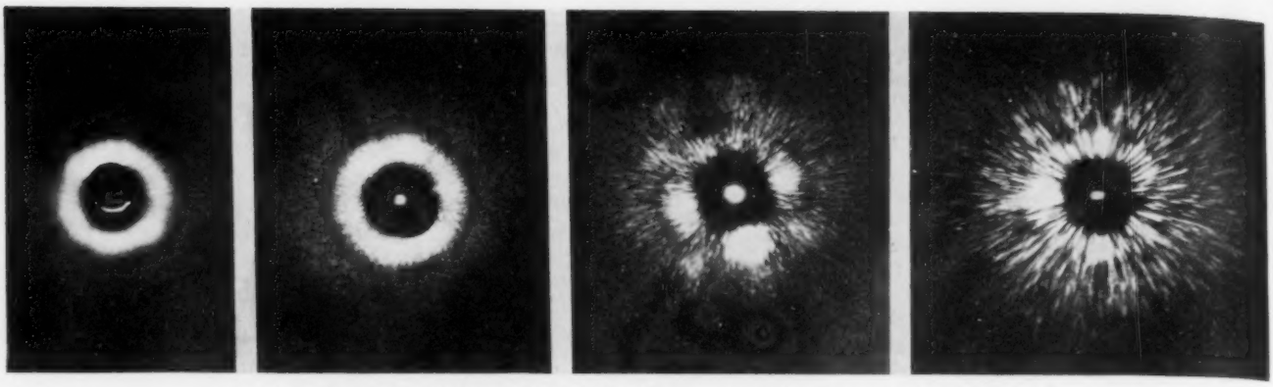

Fig. 4—Diffraction Patterns of Sheet Metal Varying in Grain Size and Internal Strain

uniform the piece tested is, if it is porous, if there are any holes, cracks or foreign particles in the weld or in the casting. The drawback is that we cannot determine from a single exposure *where* is a certain hole located in the piece tested. If we want to find out about that we have to take shadowgraphs from various directions or stereographic pictures.

These methods are, however, rather difficult and you will find very few apparatus of this type in use. Can we say anything about the presence of internal strain in a weld from these shadowgraphs, or can we learn about the reasons for the defects observed? As a rule not, although some authors hope to be able to draw some conclusions in this respect.

There is, however, a different X-ray method available now which helps in the determination of internal strain and some other data. This is the *X-ray diffraction method*. We know that every bit of metal contains many minute crystals. These crystals may be cubic, hexagonal, monoclinic, etc. Suppose we direct a narrow beam of X-rays of just one wave length against a powdered metal, let us say pure iron. The beam is diffracted by the various planes of the small crystals in the sample. We place a photographic film at a small distance from the metal and we obtain on it a diagram or diffraction pattern. The pattern shows the original beam and those parts of the X-ray beam which have been diffracted. This pattern is characteristic of iron crystals. A metal containing several crystals will give the patterns of all crystals on the film.

If a substance occurs in various types of crystals we can distinguish these crystals by means of X-ray patterns. For instance, quartz, cristobalite and tridymite are chemically identical, all being SiO_2, but since their crystals are different, their diffraction patterns are different. When it comes to an amorphous material we obtain again a pattern entirely different from that of a crystalline material.

We often want to know which compounds are present in a given mix. If the chemical analysis shows, for instance, silica, we know that free silica may be present and/or any one of many silicates may have been formed which may cause rather great differences in the properties of the product. The diffraction pattern will disclose which compounds have actually been formed. The minimum amount of a material that may be detected by this method is $\pm 1\%$. The type of crystal, together with all dimensions of the unit cell, are determined by this method. There are, however, various other data which we obtain from diffraction patterns. These data may be obtained without powdering or even touching the sample.

The X-ray pattern will give us further information regarding the grain size, for instance, of α-iron. These patterns are characteristic for various sizes of grains and for the presence of various degrees of residual internal strain or lattice plane distortion due to poor heat treatment. These patterns help in establishing the correct technique of fabrication and annealing. Similar patterns are obtained for welds or castings showing internal strain. These patterns are obtained without destroying or even touching the piece tested; nor is the drilling of holes or the measurement of cylinders required as in former methods. It is further possible to obtain, by a somewhat modified procedure, quantitative data regarding the amount of internal strain in a sample. I also want to show you a pattern of NaCl of large grain size and under considerable internal strain (Fig. 3). (NaCl gives, under ordinary conditions, some perfect rings.)

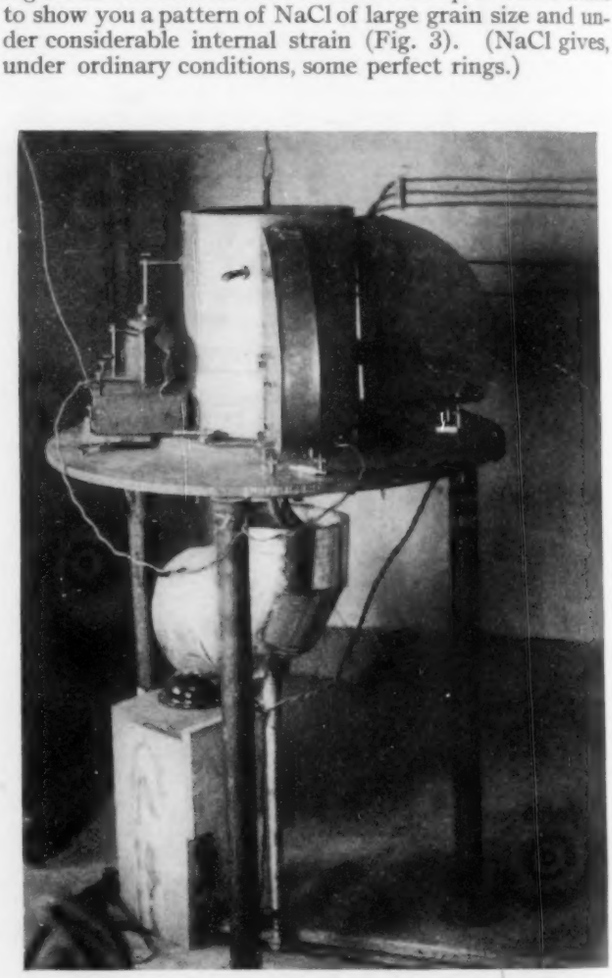

Fig. 5—X-ray Diffraction Arrangement of Author (Stand and Support Welded)

Another interesting result in this connection is the correlation of internal strain and corrosion, for instance in tin plates, etc., which I found some time ago (U. S. Patent No. 2,079,900). There is a remarkable difference in the patterns obtained from plates giving good and poor service.

Let me emphasize again that the method of testing the internal strain of metals requires no preparation of the specimen. It will not disturb the manufacturing process. It is possible for the plant superintendent to find out, within a short time, whether his material has reached the desired condition of cold working and annealing. The same methods will tell the purchasing agent whether or not material received at the plant meets his specifications.

The cost of a ready-built X-ray diffraction machine is still rather high, but the same consideration is true here as in a spectrograph: By building part of the equipment in the shop and using various odds and ends one can cut down the costs considerably. I have a diffraction pattern set-up which I built myself and which did cost less than the $2500 asked for some machines. This set-up gives patterns just as good as those obtained from more expensive machines.

It is advisable for a plant considering the use of X-ray diffraction patterns for their particular problems first to have tests made at an existing laboratory. This will demonstrate whether or not the benefits derived will justify the cost of installation.

There are many other applications of X-ray diffraction patterns. One may determine, for instance, the type of minerals in ores, clays or fluxes. One may follow the changes of crystals in metals which are being heated or which are subjected to high pressure. Metals have also been X-rayed in the testing machine or while subject to creep tests. We are also able to determine the average size of particles in a powder or a suspension. Particles too small to be detected in the microscope are being determined down to the smallest units, such as 10^{-6} to 10^{-8} cm. We can often draw conclusions regarding the particle size distribution in a material.

CONCLUSIONS

These brief remarks will give you an idea, I hope, of some practical applications of spectrographic and X-ray tests in the plant. It should be emphasized again that these tests are not intended to replace the chemical analysis but they will help the chemist and superintendent by supplementing their work. The spectrum tells us about the elements, and the X-ray diffraction pattern about the type and condition of the crystal lattice of the sample. Both methods help in explaining the peculiarities of the materials we are dealing with in our everyday practice; they further help greatly in developing new materials of desirable properties. I have also shown that these methods are not expensive to use and within reach of most modern plants. They are of great benefit in cutting down expenses and often result in saving thousands of dollars.

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EXTENSION of FUSION WELDING in Special Pipe and Pipe Fitting Applications*

By E. HALL TAYLOR†

NOVEL advances have been successfully carried into new ground recently in the fabrication of a high pressure fusion welded penstock for a Pike's Peak installation. The maximum static head on this line is 2160 feet, which under surge conditions is equivalent to 1315 lb. per square inch.

Because of the special nature of the joints for this line, it was necessary to forge upset the ends of each penstock pipe section, thus subjecting the electric fusion welded seam to extremely severe deformation. So far as is known, this is the first time such drastic forging procedure has been successfully attempted on fusion welded pipe, particularly for critical services under impact stress conditions.

What happens when electrically welded pipe is so forged? Does the weld metal forge properly? Does it show evidence of distress when upset forged double its original thickness? These and other questions were answered when we forged upset ends on pipe made by the fusion welding process. The pipe ranged in thickness from $^1/_2$ inch to $1^1/_8$ inches. Ends were thickened by forging to $1^3/_{16}$ inches and $2^1/_4$ inches.

In forging the end of a pipe to increased thickness, it is important to have a uniform structure so that no irregularities occur in the upsetting operation, that is, no buckling of metal that might form a cold shut or other forging defect. Proper heating, shape of die and amount of upset per forging stroke must all be controlled to get a good upset. When seamless or lap welded pipe was used, there was no added weld metal, hence little difficulty making an upset, given correct forging conditions. When we decided to use electric welded pipe, extreme care was used to get a very uniform weld.

The pipe was made from 60,000-lb. minimum tensile strength steel plate. The plate was rolled to tubular form and the longitudinal seam fusion welded. The weld was made by the Union Melt process in a single pass against a backing up bead. The $1^1/_8$ inch thick pipe was welded with 1400 amperes at the rate of $6^1/_2$ inches per minute. The $^1/_2$-inch pipe was welded with 1400 amperes at 17 inches per minute. Since the weld metal was subjected to the same severe upset forging as the adjacent parent metal, an excellent opportunity was presented for comparing the effect of the forging operation on each type of metal, and also to study the effect of forging weld metal in great quantities, since over 500 ends were thus forged.

A completed pipe section with ends forged is shown in Fig. 1. The finished end, before and after bolting, is shown in Fig. 2.

The forging operation shown in Fig. 3 consisted of heating the pipe end to about 2200° F., then clamping a section at a time between dies *A* and *B*, Fig. 4. Die *C* was advanced, pushing the metal back upon itself to fill the die cavity. This operation was repeated, using a second set of dies, *D*, *B* and *E*, forming the completed end.

The visual impression of the forging operation was a favorable one. The weld metal forged as easily as the parent metal and after the completed operation, the weld metal was indistinguishable from the parent metal. We concluded that from a forging standpoint, weld metal formed just as readily as the parent metal. There was no external sign of any irregularities due to lack of proper forging characteristics. To further check this, X-rays were taken through the forged weld metal. The radiographs showed weld and parent metal of identical density and free of imperfections in the upset portion as well as the adjacent pipe.

* Presented at Annual Meeting, A. W. S., Chicago, Oct. 23 to 27, 1939.
† Vice-President, Taylor Forge & Pipe Works, Chicago.

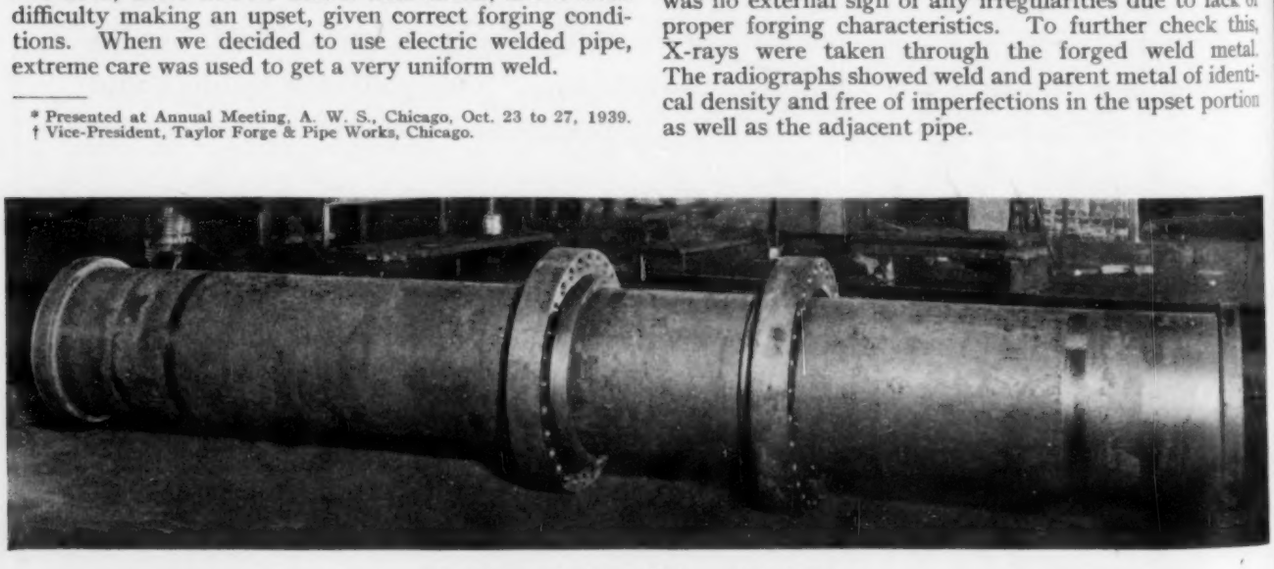

Fig. 1—Completed Pipe Section with Ends Forged

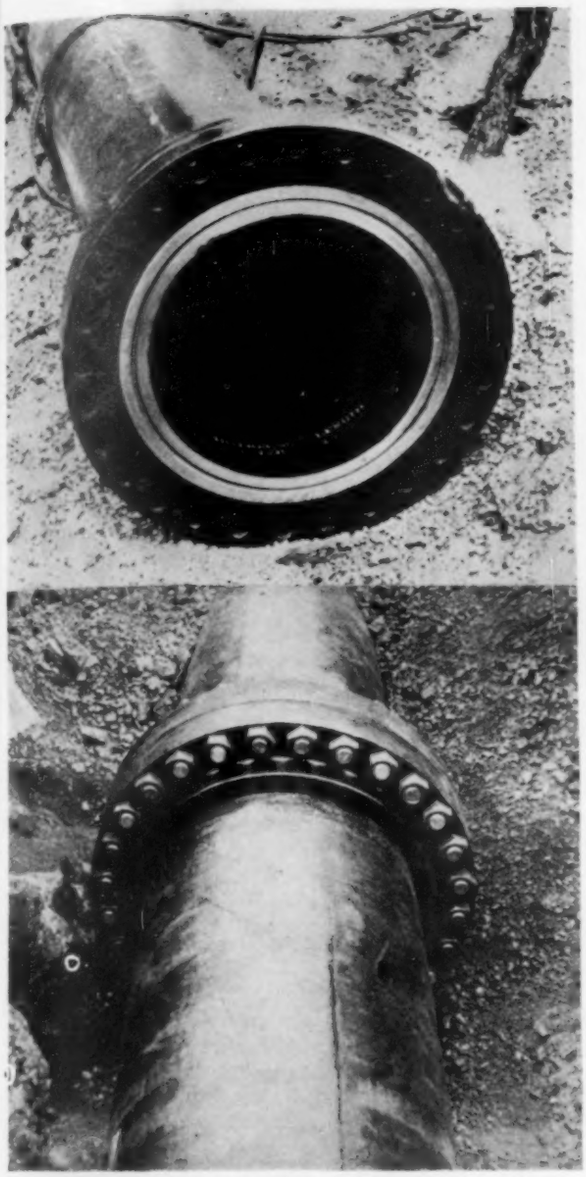

Fig. 2—Finished End Before and After Bolting

When commercial metal is rolled, macroetching of a section parallel to the direction of working shows lamination or lines resulting from the elongation of structural constituents. Such lines are known as "Flow Lines" because they indicate the direction in which the metal flowed or was worked. Displacement of known original flow lines in subsequent hot working operations will indicate the flow of the metal during the later operation.

The physical properties of steel differ markedly depending on the direction of those flow lines. Consideration, therefore, must be given in forging practice to the relation of these flow lines to the intended external loading. There should be no zones of weakness in the direction of loading—no sharp re-entrant flow of metal at change of section. A macroetched section of forged pipe end is shown in Fig. 5. In it one may note clean unbroken flow lines indicating no sharp changes in direction or improper orientation where major stresses might occur. The same is seen in the forged weld metal as shown in Fig. 6. Here also the structure shows proper flow characteristics, indicating the weld metal has good forging qualities. The flow lines, however, due to the cleanliness of the weld metal are only faintly discernible.

Perhaps our most interesting comparison is shown in Fig. 7. Here is a section of the pipe before upsetting (*A*) and here is an adjacent location after upsetting (*B*). One will note how evenly the weld increased in thickness with the plate.

The amount and type of working received by the pipe end in forging back upon itself was so controlled that no loss of unit strength was experienced even though there

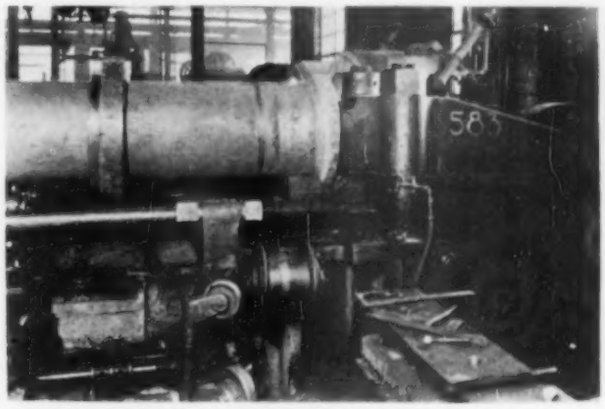

Fig. 3—The Forging Operation

was an increase in section. The tensile strength of the pipe before and after forging averaged 61,000 lb. per square inch. Tensile strength of the weld metal before and after forging averaged 62,000 lb. per square inch.

The impact value of the weld averaged slightly higher than that of the parent metal at room temperature. Parent metal was 38 ft.-lb. on the izod test and the weld metal averaged 40 ft.-lb. Low temperature tests were run to see if the same ratio held true at minus 40° F. At this low temperature there was a great difference.

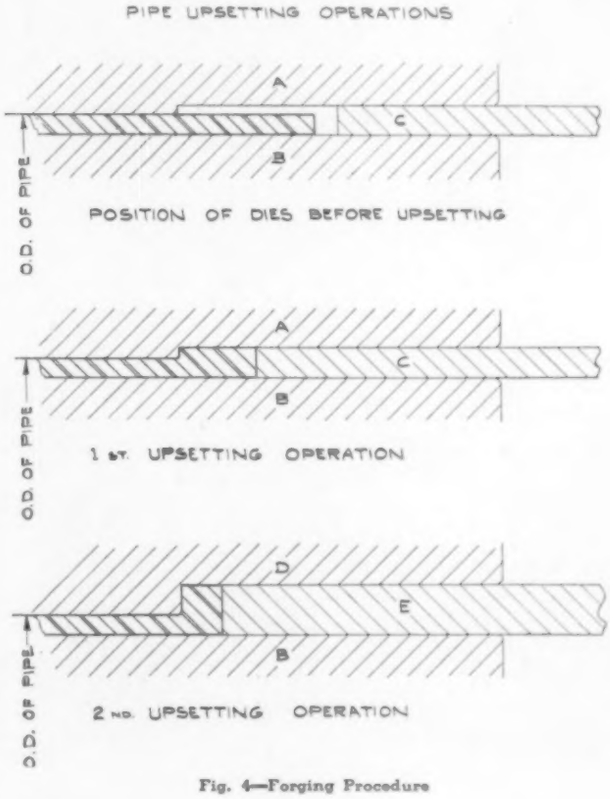

Fig. 4—Forging Procedure

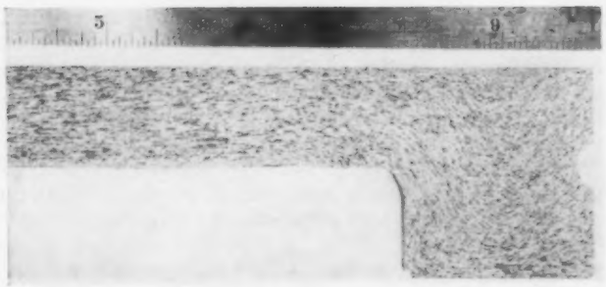

Fig. 5—Macroetched Section of a Forged Pipe End

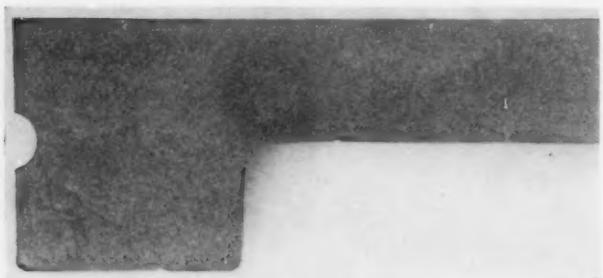

Fig. 6—Forged Weld Metal

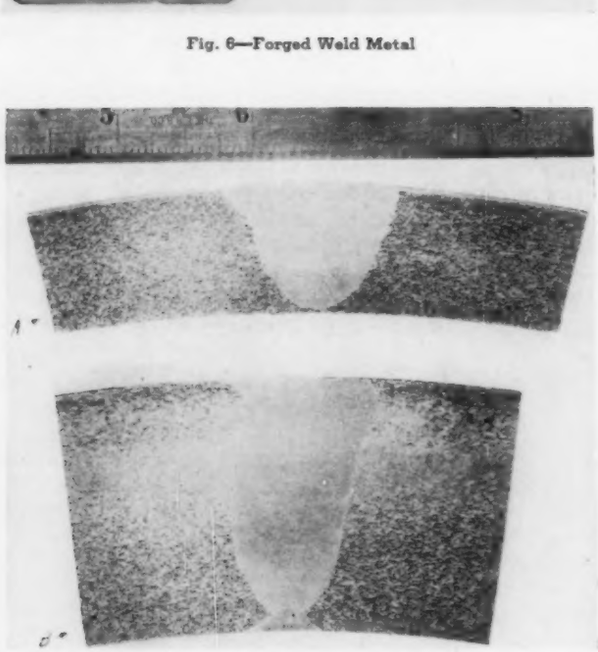

Fig. 7—Pipe Before Upsetting (*A*) and After Upsetting (*B*)

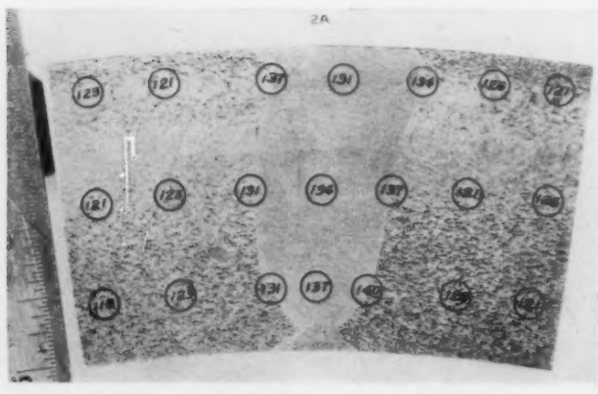

Fig. 8—Hardness Readings in Forged Section

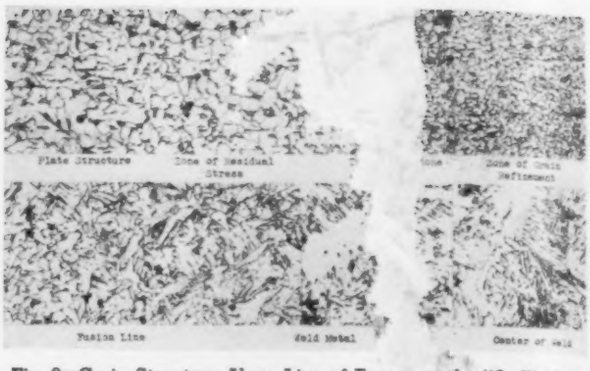

Fig. 9—Grain Structure Along Line of Fus n the "As-Welded" Condition

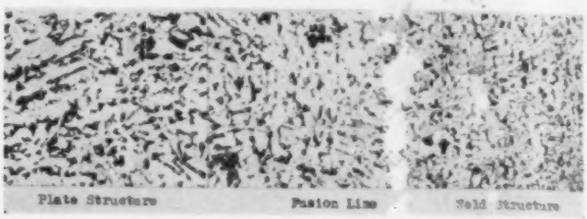

Fig. 10—After Forging Structure of Weld and Base Metal Nearly the Same

The parent metal had lost 90% of its impact value and the weld only showed a 25% drop in impact strength. Forging made no difference in these ues. The high impact value of the weld metal at low temperature is a good indication of its dense and uniform structure.

Hardness readings were taken on upset and welded circumferential sections through the weld. Practically no difference was noted. Typical values found on a circumferential section of the forged portion a shown in Fig. 8.

An interesting study was made of the grain structure along the line of fusion between the weld and parent material; Fig. 9 is in the as-welded condition. Here we see the normal transition zone between parent and weld metal. After forging, it is almost impossible to detect any difference. Here in Fig. 10 the weld and the parent material are practically the same.

Thus all tests—visual, X-ray, macro, micro, tension and izod impact (at room and sub-normal temperature) showed the weld metal to be equal to or better than the parent metal when both are subjected to identical forging operations.

An extension of fusion welding in the field of special pipe fitting applications is the growing practice of combining several standard fittings by welding, to form a special pipe fitting. Before this development, it was necessary to have special steel castings made up or to bolt several standard fittings together to meet a special condition. These older methods did not always give the desired result in economy or simplicity. In fact, the minute a pipe fitting became "special," its cost grew out of all proportion to its usefulness.

Now, special pipe fittings can be easily made to satisfy the most difficult piping conditions. Fusion welding, plus the development of standardized welding fittings, makes this possible. Fusion welding has given piping designers a new tool that enables them to make savings by simplifying their piping layouts. In places where a special fitting will save space or reduce friction loss, it is now made readily available through the use of welding.

Special high pressure steam headers can be easily constructed by joining several tees together. Reducing

Fig. 1—Group of Fittings Fabricated by Welding Standard Fittings

Fig. 12—Close-Up of One of the Welded Fittings

manifolds can be made by combining tees and reducers. Base fittings to fit any anchorage can be formed by welding plates to a welding fitting. In most cases special pipe fittings can be made by combining standard parts with a simple circumferential weld.

The type of special work to which we are referring can best be described by illustrations. Figure 11 shows a group of elbows, 45's, tees and reducers, all fabricated from standard fittings. We examine one of these in detail in Fig. 12. It is made by welding flanges to a standard seamless welding tee and then adding a welding neck to make the side outlet on the tee.

The base fitting shown in Fig. 13 is made from two standard weld ells joined to a fabricated base by welding. In Fig. 14 we have a group of elbows and reducers with

Fig. 13—Base Fitting Made from Two Standard Ells Joined to a Fabricated Base

Fig. 14—Group of Welded Elbows and Reducers with Welded Bases

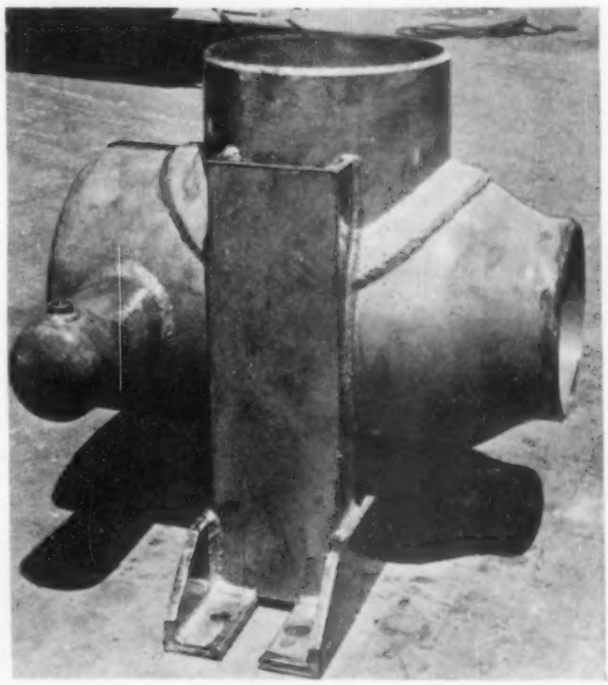

Fig. 15—Rigid Base Fitting

bases welded to them. Figure 15 shows how a very rigid base fitting is made by combining a channel and angles to a reducer.

When one considers the number of combinations made available by combining steel welding fittings and pipe and then considers the variation in sizes available by using eccentric and concentric reducers, one soon runs into truly astronomical figures. Welding makes possible this wide range of combinations. Piping fabricators are using this new tool to great advantage. They are now able to furnish a complete piping system made up of combinations of standard parts. The accuracy of dimensions of standard fittings, plus the skill of the piping fabricator, enables the fabricator to deliver complete piping units, that require only the end connections to be made to complete an installation. We believe this marks a great step forward toward a perfect piping system.

Welding Society ACTIVITIES — Related Events

NOMINATING COMMITTEE

With the approval of the Executive Committee the President has appointed the following members to constitute the 1940–1941 Nominating Committee:

Dr. C. A. Adams, Chairman, Edward G. Budd Mfg. Co., Philadelphia, Pa.

A. G. Oehler, Simmons-Boardman Pub. Co., 30 Church Street, New York City.

Prof. N. F. Ward, University of California, Berkeley.

W. W. Petry, Cincinnati Milling Machine Co., Cincinnati, O.

C. E. Loos, Carnegie-Illinois Steel Corp., Pittsburgh, Pa.

F. H. Frankland, American Institute of Steel Construction, 101 Park Avenue, New York City.

W. J. Sanneman, Tennessee Coal, Iron & R. R. Co., Birmingham, Alabama.

The By-laws require that these names be published in the Journal on or before March 1st. The Committee is required to deliver to the Secretary in writing on or before the last Tuesday in May, the names of its nominees for the various elected officers next falling vacant, together with the written acceptance of each nominee.

The purpose of publishing the names of the Nominating Committee in the JOURNAL is to provide every member with an opportunity to make suggestions to the Nominating Committee. To be effective, it is essential that these suggestions be sent in at once as, naturally, the Nominating Committee will be required to hold early meetings in order to fulfill its duties as required by the By-laws.

The offices to be filled are:

President, First Vice-President, Second Vice-President, 5 District Vice-Presidents, 4 Directors.

All of the present incumbents are eligible for reelection (their names are given in the Year Book) except in the case where these officers have served for a two-year period.

The District Vice-Presidents are elected by their districts for a term of one year and each may be reelected at any time for a second term of one year, but in no case are they eligible to serve in this capacity for more than two consecutive years.

The Directors-at-Large are selected by the Nominating Committee, with due consideration to geographic distribution.

MEETING EXECUTIVE COMMITTEE

The Executive Committee of the AMERICAN WELDING SOCIETY held a meeting on January 18th in the Engineering Societies Building.

Resolution

Resolutions were adopted concerning the death of Mr. P. G. Lang. These resolutions were prepared by a special committee consisting of Messrs. Jonathan Jones, Chairman, F. H. Frankland and A. G. Oehler. These resolutions are published elsewhere in this Journal.

Building Code

Acting upon the recommendation of the Committee on Outline of Work, the following were appointed as members of the new Building Code Committee:

Chairman—T. R. Higgins, New York District Engineer of American Institute of Steel Construction.

Secretary—L. M. Dalcher.

Other Members—J. L. Edwards, H. G. Balcom & Associates, New York, N. Y.; F. Eder, R. W. Hunt Company, New York, N. Y.; A. R. Ellis, Pittsburgh Testing Labs., Pittsburgh, Pa.; G. D. Fish, Consulting Engineer, New York, N. Y.; F. H. Frankland, American Inst. of Steel Construction, N. Y. C.; C. F. Goodrich, American Bridge Company, Pittsburgh, Pa.; LaMotte Grover, Air Reduction Sales Company, New York, N. Y.; R. S. Hale, Consulting Engineer, Washington, D. C.; Jonathan Jones, Bethlehem Steel Company, Bethlehem, Pa.; M. P. Korn, Consulting Engineer, Buffalo, N. Y.; A. E. Marble, Jones & Laughlin Steel Corp., Pittsburgh, Pa.; C. W. Obert, Sr., Union Carbide & Carbon Res. Labs., N. Y. C.; R. Saxe, Consulting Engineer, Baltimore, Md.; Design Engineer, Bureau of Yards & Docks, Washington, D. C.; A. Vogel, General Electric Company, Schenectady, N. Y.

Other Committees

A Non-Destructive Tests Committee was authorized consisting of H. L. Whitemore, Chairman, L. M. Dalcher, Secretary and C. A. Adams, N. L. Mochel and J. W. Owens.

The Executive Committee appointed Mr. Ira B. Yates of the Wilson Welder & Metals Company as the A. W. S. representative on the A. S. A. Standardization Project "Preferred Voltages—100 Volts and Under."

Mr. L. M. Dalcher, Assistant Technical Secretary of the Society was made Secretary of the following committees, subject to their approval:

Filler Metal Specifications Committee
Committee on Rules for Field Welding of Storage Tanks
Committee on Definitions and Chart
Committee on Minimum Requirements of Instructions for Training of Welding Operators in Trade Schools

Mr. A. F. Davis was added to the Committee on Minimum Requirements of Instructions for Training of Welding Operators in Trade Schools.

Welding History

From time to time, the Society has received suggestions that a history on welding ought to be compiled covering all processes, personnel and early applications. The Executive Committee appointed a small committee consisting of Mr. H. S. Smith, Chairman, J. H. Deppeler, R. S. Donald, C. A. McCune and W. Spraragen, to look into the matter and report back to the Executive Committee their recommendations.

Standard Tests for Welds

Report on Standard Tests for Welds was approved as submitted for publication in the Journal and in separate bulletin form.

Definitions and Charts

The work of the Definitions and Charts Committee has been under way for a period of several years. The report as submitted was approved for publication in THE WELDING JOURNAL and in separate bulletin form.

Disbandment of Montana Section

The Montana Section was organized December 2, 1936. While the membership consisted largely of the Operating group, well-attended meetings were held quite regularly throughout a two-year period. As the project neared completion, men were leaving for other parts of the country and it was not possible to secure enough interest to hold meetings.

Acting upon the request of the Secretary of the Montana Section for the disbandment of the Section, the Executive Committee voted its disbandment.

Appointments

The following additional appointments were made:

Publicity Committee—W. V. Merrihue of General Electric was replaced by R. D. Jordan of the same Company.

Meetings & Papers Committee—J. J. Murphy of The Linde Air Products Co. was added, with Mr. E. A. Doyle of the same company as alternate. Also added to this Committee was Mr. Malcolm S. Clark, Chairman, Publicity Committee, Resistance Welder Manufacturers Assn.

The financial statement submitted indicated that the Society was operating from a financial viewpoint more favorably than estimated in the adopted budget.

McK STAINLESS ELECTRODES Certified
THE McKAY COMPANY certifies that the electrodes in this package are part of a lot that have been tested within the recommended current and voltage ranges. The resultant Weld Deposit when uncontaminated by parent metal was found to analyze as shown:
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Nickel 10.21
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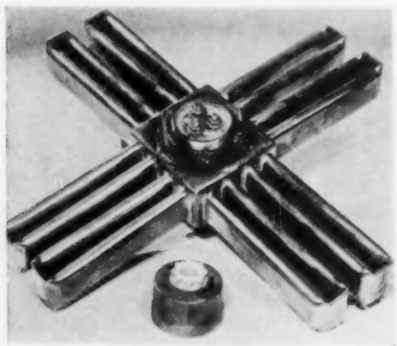
JOINING THIN TUBING TO CAST BRASS

In making an immersion type urn heater, the Harold E. Trent Co. of Philadelphia had a problem of joining eight flat tubes to a cast brass center. The tubes, as illustrated in this case, are copper, but to meet some conditions a steel alloy tube is used. An electrical heating



16 Joints Made with Temperature Brazing Alloy

unit must be assembled inside the tubes before the joint is made. After fluxing the brass center and the tubes, the unit is assembled on a frame or jig and heat is applied with a torch. There are 16 joints to be completed which normally have to withstand pressures up to 100 lb. per square inch and stay leak-tight under conditions of repeated heating and cooling. The thin section of the tubing makes it desirable to keep the heat for making the joints as low as possible. The brazing alloy used, Easy-Flo, was selected because of its low flow point—1175° F.—and because its silver content assured a ductile joint and strength as high as the tubing. By concentrating the heat on the heavier cast brass center, joints are made without damage to the thin metal tubing. As the center section reaches a dull red heat, the brazing alloy is applied to the joint and the heat is shifted momentarily to the tubing to assure a uniform brazing heat. The finished joints are smooth and even, requiring no finishing work. The same brazing alloy is used on both the copper and steel alloy tubing. The free flowing and rapid penetration of the brazing alloy make this a fast and economical method of doing this difficult job.

MAIN AVENUE BRIDGE CLEVELAND, OHIO

Main structure is ten spans of cantilever trusses 2520 ft. long, width is 82 ft. River span is 400 ft. long, roadway 120 ft. above water level. Cantilever erection. Two deck, steel column and beam section 750 ft. long, 82 to 138 ft. wide, 40 ft. spans. Four span continuous girders are 858 ft. long. Maximum span is 270.8 feet. Depth of girders varies from 12 to 16 ft. Three-girder system under deck 55 ft. wide. Riveted steel rigid frame bridges 1400 ft. long, spans vary from 13 to 122 feet. Reinforced concrete rigid frame

Photo courtesy Fred L. Plummer, Chief Design Engineer

and bent bridges 1500 ft. long, spans 27 to 40 ft.

Two three-span all-welded steel rigid frame bridges. Trusses rest on hollow concrete piers, continuous girders on steel and concrete piers anchored to foundation mat. Retaining walls 6600 feet long vary in height up to 34 ft. Bridge deck is concrete filled steel grid $4^1/_2$ inches deep.

Truss members are box or *H* section, with no lacing, *K* type, bracing is used. Expansion dams made of cast steel, also flame cut from $2^1/_2$-inch steel plates. Center dividing strip. No crown. Drainage longitudinal. Welded and cast cross drains. Welded steel railing and light standards. Sodium vapor lamps. Automatic control. Length of sewers, 4 miles. Length of railing; 3 miles. Length of light conduit, 7 miles. Steel, 24,000 tons. Concrete, 55,000 cu. yds. Paint, 16,000 gal. Excavation 125,000 cu. yds.

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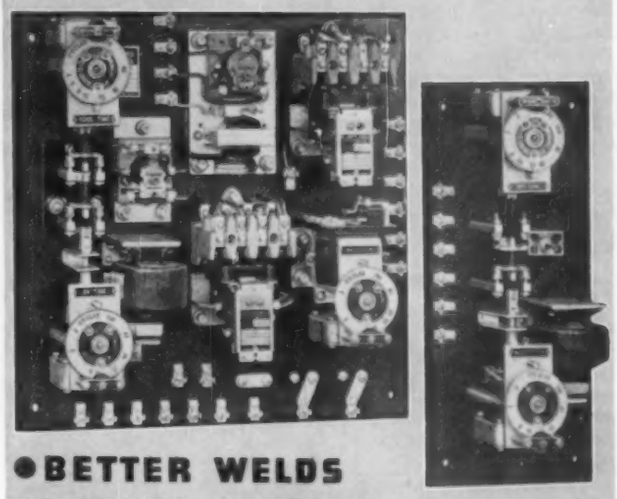

● BETTER WELDS
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● INCREASED MACHINE CAPACITY

Interrupted spot welding consists of breaking the flow of current at controlled intervals while the electrodes remain clamped to the work. The process has advantages in the fabrication of thick cross sections, unusual shapes and hot rolled materials because—

1. Alternate heating and cooling intervals raise the metal to fusion temperature without overheating and annealing the electrodes. Reduces maintenance cost.
2. Brittle welds are avoided and the effect of scale or rust on the material surfaces is minimized. Better product.
3. Welding machine capacity for thicker materials is increased by applying several smaller current impulses in place of a single one of high value. Smaller machine investment.

The new Square D timer panels for air-operated welding machines can be equipped to automatically control the Heat and Cool periods of interrupted spot welding as well as the Squeeze, Hold and Off periods of the welding cycle. Pneumatic time delay mechanisms and high speed relays are interconnected in a circuit arrangement which eliminates sensitive adjustment and provides independent control of all functions. Similar timers are available for foot-operated and motor-driven machines.

Square D timers and welder panels are not costly and are easy to operate. *Write for Bulletin 38-017.*

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Total length 8000 feet. Length of traffic lanes, 13 miles. Total cost, $7,200,000, including $1,620,000 for right of way. Main bridge opened to traffic on October 6, 1939. Lakefront ramp to be completed during 1940.

SQUARE D AQUIRES KOLLSMAN

On December 28th, the Square D Company bought the Kollsman Instrument Company for about $4,000,000.

Square D has specialized in motor control and switch equipment in the electrical field. Kollsman has specialized in equipment for the aviation industry, thus at first glance the merger may not be apparent. But Square D sees a big future for aviation and senses the possibility of Kollsman's ideas and apparatus in general industry as well as aviation.

Paul Kollsman, who developed several special instruments for aviation such as altimeters, accelerometers and tachometers, having a degree of precision making them outstanding for aircraft use, built his business in a few years. Now he prefers to devote his attention to research and invention rather than to the details of business so the current deal was mutually agreeable.

Acquisition of Kollsman gives Square D a greater diversity of product, a broader market and an opportunity to apply the precision ideas of Paul Kollsman to its general line of equipment.

SS EXPORTER

The Exporter, first of four fast freighters being built at a nationally known shipyard, was launched recently, exactly 8 months and 8 days after her keel was laid. This feat was exceedingly unusual for a ship of her size—the ship 473 ft. long, having a gross tonnage of 14,450. With her sister ships, the Exporter is expected to meet this country's need for more and faster cargo ships. Compared with past speeds of 10 to 12 knots, the new ships are designed for a speed of 16½ knots, with a steaming radius of 15,000 miles at this speed.

Photo courtesy Harnischfeger Corporation.

S. S. Exporter, New Pride of the U. S. Marine Service, Goes Down the Ways

The use of arc welding made an important contribution to the speedy launching of the Exporter. The Exporter's hull was approximately 40% welded. The construction of the others will parallel that of the Exporter. This work covers all the downhand welding on the decks, tank tops, bulkheads, pipe tunnels, shaft tunnels and any other welding which could be done in a downhand or semi-downhand position.

STANDARD METAL DIRECTORY

This is the Eighth Edition of the Standard Metal Directory, the previous one having been published in 1936. The 1940 edition contains over 600 pages.

The directory is divided into four special sections embracing: Iron and Steel Plants; Ferrous and Non-ferrous Metal Foundries, Metal Rolling Mills; Smelters and Refiners of non-ferrous metals.

In these lists will be found more than 11,000 detailed reports on steel mills, ferrous and non-ferrous metal foundries, metal smelters, metal rolling mills, and non-ferrous metal plants in the United States and Canada, arranged geographi-

Buy "Proven Fluxes" with Years of Guaranteed Satisfaction behind them
The Trade-Name is "ANTI-BORAX"

Ask For Them *Unequaled for Quality*

A Flux for every metal: Cast Iron Welding Flux No. 1.; Brazing Flux No. 2; Braz-Cast Flux No. 4, for bronze-welding cast iron; "ABC" Aluminum Flux No. 8 for sheet Aluminum and all alloys of Aluminum; Stainless Steel Flux No. 9; Silver Solder Brazing Flux No. 10; "Anti-Borax" Tinning Compound No. 11.

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Jaw Plates, Gyratory and Roll Crushers, Shovel Teeth, Hammers, Tractor Tread Grousers
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Reg. U. S. Pat. Office. U. S. Patents 1,876,738—1,947,167—2,021,945

11 to 13½% Manganese Nickel Steel

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STULZ-SICKLES CO. *Sole Producers* 134-142 Lafayette St., Newark, N. J.

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- Welding Torches
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- Regulators
- Outfits

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282 E. ONTARIO CHICAGO

THOMSON

HEADQUARTERS FOR
Manual and Automatic SPOT, SEAM, BUTT, FLASH, PROJECTION, PORTABLE GUN, FABRIC and SPECIAL RESISTANCE WELDING PRODUCTION EQUIPMENT

Write for FLASHES, a monthly magazine of Resistance Welding News and information. Sent free on request by

THOMSON-GIBB ELECTRIC WELDING CO.
General Offices: 166 PLEASANT ST., LYNN, MASS.

If one were to single out one particular advantage, among the many which make VICTOR cutting and welding torches famous, it would be this one:

They COST LESS to operate!

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WELDING EQUIPMENT DIVISION
844-850 FOLSOM ST. SAN FRANCISCO
3821 SANTA FE AVE. LOS ANGELES
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cally and alphabetically. These reports give the name of the company, its capitalization, when organized, the location of its plants, the address of the main office, company officers, purchasing agent, sales manager, plant equipment, number of employees, products manufactured, annual productive capacity, and type of raw and semi-finished materials consumed.

The directory is an excellent and valuable reference for the steel and metal industries and is of special value to purchasing agents and sales managers.

The Standard Metal Directory is published by the Atlas Publishing Company, 150 Lafayette Street, New York. The directory sells for $10.00 a copy.

STAINLESS STEEL COMMERCIAL TRAILERS

According to an announcement just released by the Fruehauf Trailer Company of Detroit and the Edward G. Budd Manufacturing Company of Philadelphia, the Fruehauf Company is placing on the market a new line of light-weight, stainless steel freight trailers fabricated by the Budd "Shotweld" process.

Production will start immediately. Shipment of these new trailers will be made from the Fruehauf main plant in Detroit, as well as from its branch plants in Los Angeles, Kansas City and New Orleans.

Fruehauf stainless steel trailer bodies are of the same fundamental construction that has made stainless steel outstanding for the building of modern streamline passenger trains adopted by leading railroads during the past few years.

These new Fruehauf trailers will combine the essential features of light-weight, great strength and rigidity and all the fine appearance provided by the gleaming richness of polished metal. With the stainless steel "Shotweld" construction a saving in weight is achieved which results in marked reduction of hauling costs.

ALL-WELDED BARGE

Recently built by American Car and Foundry Company for the Hill Dredging Company of Atlantic City, this all-welded barge will be used for laying dredge pipe. Because of its high corrosion resistance, the high tensile strength of USS Cor-Ten could be utilized to good advantage for weight saving and $^1/_4$-inch side and bottom plates were substituted for $^5/_{16}$-inch plates; $^3/_{16}$-inch for the $^1/_4$-inch bulkhead plates formerly necessary. Bars and shapes were reduced in the same proportions. In the 40-ft. boom, USS Cor-Ten replaced wood with a considerable weight saving. All welding was satisfactorily handled by manual electric arc equipment using coated rods.

DRAVO TONNAGE

A record year for tonnage launched has been reported by Dravo Corporation of Pittsburgh. During 1939, 136 welded steel hulls, a total of 65,904 gross tons, slid from the Company's ways at Neville Island, Pennsylvania, and Wilmington, Delaware. Of these 136 hulls, 134 were of 100 gross tons or over.

This tonnage tops the previous banner year of 1929 when 55,230 gross tons were launched. It is interesting to note that 1929 tonnage cover 163 hulls which indicates the tendency toward larger water transportation units.

The largest unit of the year was the wharf boat for Green Line Steamers, 296 feet x 57 feet x 6 feet, tonnage 4840. The two smallest were identical work boats, 45 feet x 10 feet 7 inches x 5 feet 8 inches, of 21 tons each.

RESOLUTION—ADOPTED BY THE EXECUTIVE COMMITTEE JAN. 18, 1940

Whereas,

Our beloved colleague Philip George Lang, Jr., has been taken in death at the crest of his mental vigor, his personal popularity and his many-sided usefulness; and

Whereas,

He performed a notable service to this Society and to Industry as Chairman of the Committee which prepared the first American Specification for the Design, Construction and Repair of Bridges by Fusion Welding; producing it with unusual expedition because of his forceful leadership and sense of proportion, and ensuring its wide acceptance in engineering circles by reason of his standing therein: and

Whereas,

He further served this Society as its President, during the critical year commencing November 1937, harmonizing divergent viewpoints and obtaining greater recognition of the Society's place as a technical and engineering body; and later served as a member of its Board of Directors, Executive Committee, Finance Committee, Membership Committee, and Conference Committee on Welded Bridges, devoting time, energy and original thought to improving the effectiveness of the Society, which benefited greatly by his unusual ability to integrate the work of its Committees, and

Whereas,

He brought to this Society a wealth of engineering and human experience, and was actuated in his services by an unselfish desire to be of assistance;

Therefore,

Be it Resolved, by the (Board of Directors of the) AMERICAN WELDING SOCIETY, that this Society shall give expression to its sense of a great loss in the death of Philip George Lang, Jr., a loss to the organization in having no longer available his deep interest and effective service, and a personal loss to each of those who knew, admired and enjoyed him; and further

Be it Resolved, that this Resolution shall be published in the Journal of the Society, and shall be suitably engrossed and delivered, as a memorial, to the family of the departed.

A MESSAGE FROM OUR NEWLY ELECTED HONORARY MEMBER

1939 Dec. 26

Mr. W. Spraragen, Editor,
THE WELDING JOURNAL,
29 West 39th Street,
New York, N. Y.

Dear Bill,

I should like to use the medium of the JOURNAL to express my great appreciation of everything connected with the dinner which was tendered to me on December 20th, at the Engineers' Club in New York. I wish to convey my hearty thanks:

To the Executive Committee, and Officers of the SOCIETY, for sponsoring the honor:

To the New York Section, for carrying out the arrangements;

To the participants in the very funny and original burlesque, for their impersonations;

To the forty-odd men who wrote and wired their good wishes;

To everyone who attended the affair, just because they were present.

The able manner in which the dinner was conducted, and the sentiments it reflected, will be remembered by me with gratitude as long as I live.

Very truly,
F. T. LLEWELLYN

BACK NUMBERS OF WELDING JOURNAL

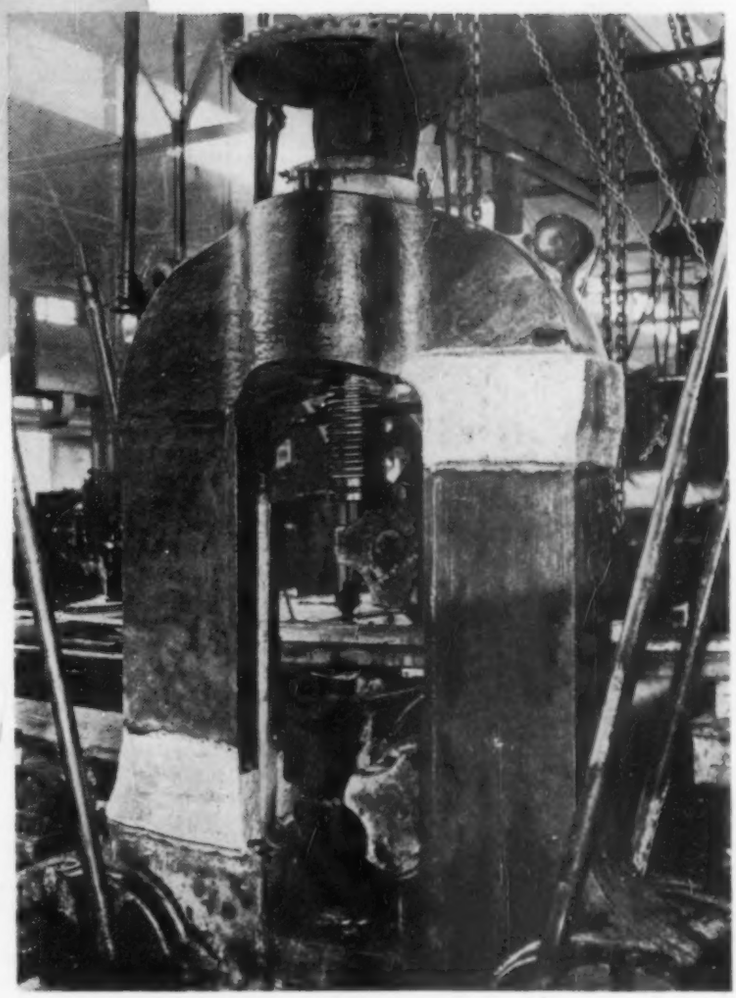
Although the Society does not have back numbers of all of its Journals as many of them are out of print, it does have copies of most of the issues. Members and others desiring to secure copies of back numbers may do so by placing orders at the following rates: Single copies, any issue, 50¢; lots of 5 to 10—40¢ each.

EMERSON JOINS PITTSBURGH PIPING

R. W. Emerson, formerly with the Westinghouse Electric and Manufacturing Company, East Pittsburgh, is now affiliated with the Pittsburgh Piping and

How strong is a 400-lb. Tobin Bronze weld? How quickly can it be made?

The story of the repair welding of this 15-ton roll housing reveals the answers to these important questions...



LAST March 8, this huge housing on a 33" rolling mill cracked resoundingly and thundered to the floor. Production orders were heavy on this particular mill and a replacement could not have been made for eight or nine weeks. To save time, two temporary repair-welds with Tobin Bronze were tried. Welders, working steadily in two shifts, used 400 lbs. of Tobin Bronze 3/8" welding rods for each weld; consumed only nine days to complete the work. On March 17 the housing was back in place ready to go... So much for how quickly welds of Tobin Bronze can be made.

Production was resumed, the plant superintendent hoping that the repaired housing would stand up under terrific operating pressures of the rolls until a new casting could be obtained. Six months later that mill was still rolling its quota of metal. *What's more,* during this period, a roll neck broke in the housing. The abnormal stress that brought about the fracture in the heavy roll was absorbed by the welded housing with no sign of failure. Such service is proof positive of the high strength of properly made Tobin Bronze welds in cast iron.

Tobin Bronze welding rods are stocked by all leading supply houses. Make sure that when you buy Tobin Bronze it bears the trade-mark "Tobin Bronze—Reg. U. S. Pat. Off."—only then you will be getting the genuine. 40115

ANACONDA

Anaconda Welding Rods

THE AMERICAN BRASS COMPANY, General Offices: Waterbury, Connecticut

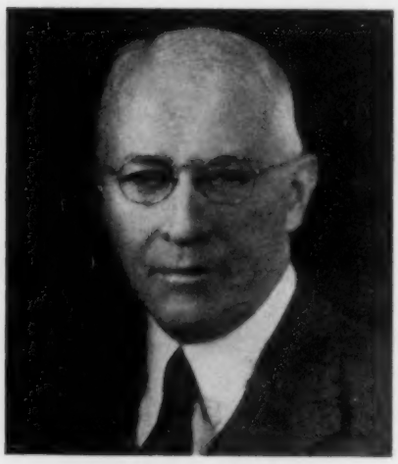
In Canada: Anaconda American Brass Ltd., New Toronto, Ont. • Subsidiary of Anaconda Copper Mining Company

Equipment Company, Pittsburgh, Pa., in the capacity of Metallurgist and Welding Engineer.

JOHN A. ROEBLING'S SONS COMPANY APPOINTS NEW GENERAL MANAGER

Charles G. Williams, formerly Vice-President in Charge of Purchasing and Manufacturing Operations for the fifteen plants of the American Chain and Cable Company, Inc., has been appointed General Manager of the John A. Roebling's Sons Company, Trenton, New Jersey.

Mr. Williams was born in Hartford, Conn., on August 25, 1885. He attended the Phillips Andover School in Andover, Mass., and later received his degree in Mechanical Engineering from the Sheffield Scientific School, Yale University, Class of 1908.



Charles G. Williams

After leaving college, he was employed for a time by the Terry Steam Turbine Company of Hartford, Conn., as a member of their Engineering Department.

In January 1913, he was made Purchasing Agent of the American Chain and Cable Co. plant at Oneida, N. Y. Shortly after the acquisition of the Standard Chain Company in 1916, he was appointed General Purchasing Agent of all plants of the company and was, in 1928, made General Production Manager. In 1930, he was made a director of the company and, in 1936, was appointed Vice-President in charge of all Manufacturing Operations in the fifteen plants of the company.

Mr. Williams will assume his duties with the John A. Roebling's Sons Company on March 1, 1940.

PLANOGRAPH

The Airco No. 10 Planograph, a new 4-page bulletin published by Air Reduction Sales Company, New York, describes this gas-operated cutting machine designed for cutting straight lines, rectangles, circles and irregular shapes from ferrous metal of any thickness within the present practical limits of the cutting torch.

The bulletin contains a complete pictorial representation of the planograph, as well as operating details and specifications. Features of the device are listed, such as its wide cutting range, single- or two-torch operation, centralized location of electrical controls, interchangeable devices for manual tracing or magnetic and templet tracing, and central gas control unit.

Copies of this bulletin may be obtained by writing Air Reduction Sales Company, 60 East 42nd Street, New York, N. Y.

WELDING REVIEW 1939

By W. W. Reddie*

Progress in arc welding during the year has been outstanding, notably in the fields of carbuilding, shipbuilding and heavy machinery construction.

This has not been due so much to new developments in welding machinery, electrodes and technique as to the expansion in the business of the industries named. It is a tribute to welding manufacturers collectively that their products were developed to the point where they were ready for the immediate service of industry at a time when it was essential to increase production from a low level to peak proportions, literally, almost overnight.

The increase in the use of alternating current as a source of welding power, using transformer type welders, has been outstanding during the year. This has taken two directions; first, the use of unusually large amounts of power for automatic systems of welding, and, secondly, the use of unusually low welding currents.

Alternating current transformer type welders have been found to supply the need for high-current, heavy-duty welding most efficiently and economically and the development has taken the trend to 1000 ampere units. The units may be operated singly or in parallel; for example, some of the largest installations use four 1000 ampere welders, with various combinations of single and parallel operation to provide current ranges from 200 to 4800 amperes. The use of these automatic systems has tremendously speeded up welding operations in shipbuilding and carbuilding.

In the field of medium and light manual welding operations, improvement in alternating-current electrodes has stimulated the use of alternating current. Electrodes have been improved to the point where alternating-current welders are readily used with current values down to 20 amperes with low open circuit voltages. The development of small alternating-current welders, with a wide variety of types of electrodes has brought the use of arc welding within the range of many small welding operations where it was previously unjustifiable on account of limited requirements. Economy, of course, requires that all types of alternating-current electrodes perform with equal success when used with direct-current arcs.

The use of Diesel engine driven welding generators in the construction field, for locations where electric power is not available, increased during the year. Equal reliability with gas engine drive and lower operating costs will justify the continuous use of more Diesel powered units.

Transformer type alternating-current welders are being used very successfully on construction work in locations where electrical power is available. Earlier questions as to the adaptability for overhead and vertical work in out-door construction have been settled by actual use of the machines. A notable example occurred in the erection of steel for the thirteen-story Women's Hospital in Pittsburgh.

The broad background of development in welding machines, electrodes and welding procedure which took place over a period of several years past has without doubt been a leading factor in facilitating the rapid increases in production, which the heavy manufacturing industries were called upon to provide during the latter months of 1939.

* Welding Division, Westinghouse Elec. & Mfg. Co., East Pittsburgh, Pa.

REMARKS BY C. A. ADAMS WHEN PRESENTING MILLER MEMORIAL MEDAL AND CERTIFICATE TO C. J. HOLSLAG

From the standpoint of the present state of the art of welding, it is difficult for any but the old timers to realize how little was known in the early days and how slow the progress of evolution. Unfortunately, most of us are like sheep and follow the leader, or accept the dictum of some assumed authority without doing any real thinking, or questioning of tradition.

In this country we were almost unbelievable slow and stubborn in two directions: first, we clung to bare wire welding almost exclusively for at least ten years after the successful commercial use of covered electrodes in England; second, we refused to acknowledge the possibilities of A.C. arc welding throughout the same decade.

To those who break through traditions or the habits of the sheep and urge us on to real progress we usually give the title of pioneers. The Miller Medalist today was a real pioneer in both of the fields referred to. He urged the use of A.C. welding, he patented, built and marketed, on a small scale, successful A.C. welding equipment many years before any large fabricator woke up to its possibilities. He did the same with covered electrodes and still holds some of the most fundamental patents in this field.

I, therefore, consider it an honor as well as a real pleasure to present Mr. Claude J. Holsag as the Miller Medalist for 1939. If Sam Miller were here, I am sure he would applaud the award.

CORRECTION NOTICE

In the article by F. C. Dull appearing in the January issue, the last sentence at the bottom of page 40, should read: "After almost 15,000,000 passes the unhardened bed is badly scored and shows obvious wear, whereas the flame hardened bed on the other hand shows no wear whatsoever."

for strong, shock-resisting welds!

● Hi-Tensile "G" gives you an especially tough and ductile weld. This makes it a favorite on jobs that must later be exposed to considerable shock and strain. ● Hi-Tensile "G" lays a smooth, dense bead—and lays it smoothly and quietly and rapidly with little spatter and slag loss. ● This electrode is designed for down-hand and horizontal fillet welding and meets the requirements of all regulatory specifications for these classes of work. ● Your local Page distributor will give you complete information on Hi-Tensile "G" and other Page electrodes.

BUY ACCO QUALITY *in Page Welding Electrodes; Page Wire Fence; Lay-Set Preformed Wire Rope; Reading-Pratt & Cady Valves; Campbell Abrasive Cutting Machines; American Chains; Ford Chain Blocks.*

PAGE STEEL AND WIRE DIVISION · **MONESSEN, PENNSYLVANIA**

AMERICAN CHAIN & CABLE COMPANY, Inc.

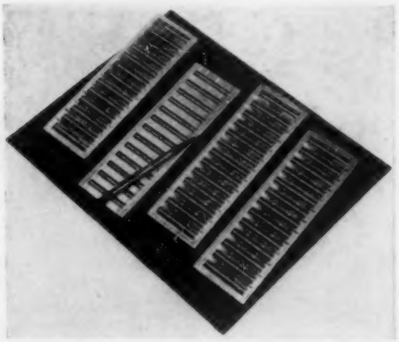
AMERICAN CHAIN DIVISION • AMERICAN CABLE DIVISION • ANDREW C. CAMPBELL DIVISION • FORD CHAIN BLOCK DIVISION • HAZARD WIRE ROPE DIVISION • HIGHLAND IRON AND STEEL DIVISION • MANLEY MANUFACTURING DIVISION • OWEN SILENT SPRING COMPANY, INC. • PAGE STEEL AND WIRE DIVISION • READING-PRATT & CADY DIVISION • READING STEEL CASTING DIVISION • WRIGHT MANUFACTURING DIVISION • IN CANADA: DOMINION CHAIN COMPANY, LTD. • IN ENGLAND: BRITISH WIRE PRODUCTS, LTD. • THE PARSONS CHAIN COMPANY, LTD. • *In Business for Your Safety*

NEW PRODUCTS

The Society assumes no responsibility for the validity of claims in this Section

BEARINGS

A group of "ladder-type bearings" manufactured by the Bantam Bearings Corporation, South Bend, Indiana.



These bearings were made to specifications for a prominent builder of resistance welders. Purpose is to handle thrust-loads with accuracy in spot-welding applications.

WELD-O-TRON

This new low-current electronic welder for precision work can weld with currents as low as only 5 amperes using new 1/32-inch and 3/64-inch electrodes that have been especially developed for use with the new welder. You can now weld sheets as thin as 32 gage. Hardware, cutlery, small alloy castings, light seamless tubing, business machines, automobile bodies, streamlined trains and airplanes all offer fields for the use of this new welder.

The development of new equipment for electric arc welding, and new methods of handling it, has made rapid progress in the past few years. . . . but until now it was not feasible to produce satisfactory arc welds in metals lighter than approximately 18 gage without seriously burning the metal and destroying many of its vital properties.

WELD RECORDER

Now available to all industries after having proved its advantages and reliability. For more than a year it has been successfully used with spot welders in the production of aircraft and rail cars.

Records the character of the electrical input for every weld, as compared with allowable limits.

Records, gives an audible signal and locks out the welder when the input varies more than the allowable limits for satisfactory welds.

Prevents subsequent welding until a push button is pressed. General Electric Company, Schenectady, N. Y.

STAINLESS-CLAD STEEL

A new 24-page booklet which contains useful information on Jessop Silver-Ply stainless-clad steel for both buyers and fabricators of stainless equipment, has just been issued by the Jessop Steel Co., 628 Green St., Washington, Pa.

Silver-Ply is a composite sheet or plate consisting of a layer, or ply, of stainless steel which has been firmly welded to a mild steel backing during the rolling process. The new booklet describes its advantages over solid stainless, how it is manufactured into sheets and plates, and how it is fabricated into finished equipment.

A free copy of the new booklet will be sent free to anyone requesting it on his company letterhead.

WELDING BLOWPIPE

Especially Designed for Light Welding

A new oxyacetylene welding blowpipe, for welding light-gage metal has just been announced by The Linde Air Products Company, a Unit of Carbide and Carbon Corporation. Although this blowpipe, known as the Oxweld (Type W-29) Welding Blowpipe, was specially designed for welding in light production work and in aircraft construction, its field of usefulness extends to all applications in which metals up to 3/8 inch thick are to be joined.

The New Oxweld Welding Blowpipe for Light Welding

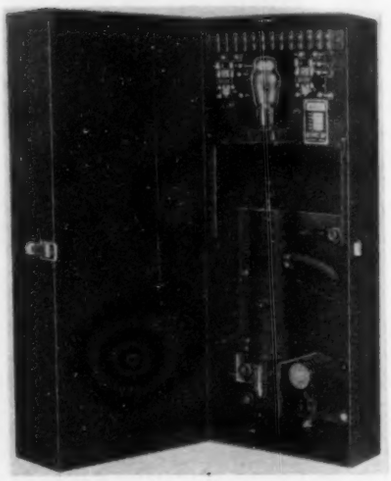
Ease of Handling

Its light weight (15 oz.), small size and slender lines make it unusually well suited to welding in relatively inaccessible places, or for production line work. Both valves on the W-29 are located at the forward end of the handle where they may be readily adjusted by thumb and forefinger, leaving the other hand free. The "pencil point" welding flame is concentrated yet "soft" enough for excellent control of the welding puddle.

Further information about this blowpipe, which replaces the W-15 Welding Blowpipe in the Oxweld line, can readily be obtained from any office of The Linde Air Products Company.

SPLIT-CYCLE TIMING FOR WELDING

Ability to positively control welding time to a half-cycle of current on any resistance welder is provided by a new weld timer just announced by Weltronic Corporation, 2832 E. Grand Blvd. Detroit, Michigan.



Built as a separate unit the timer may be adapted to virtually any standard resistance welding machine. It is recommended particularly for welding thin section stainless steel, aluminum, brass screen, copper lugs and similar applications where unusually high heat and closer control of welding time than offered by conventional timers are essential.

The new timer provides a full positive half-cycle in order to permit use of the highest heat in the shortest possible time.

HARD-FACING ROD

Haynes "93" hard-facing rod, a new alloy welding rod for hard-surfacing wearing parts, has just been announced by Haynes Stellite Company, Unit of Union Carbide and Carbon Corporation. It is recommended for use where severe abrasion, accompanied by only a moderate amount of impact, is encountered. It has already proved successful on dredge pump impellers, cement clinker, crusher rolls, slag crusher roll teeth, cinder, crusher rolls, tamper feet for cinder block manufacturing, tube bending mandrels, farm implements and other wearing parts.

Haynes "93" alloy rod is of a ferrous composition and contains chromium, molybdenum, cobalt and other alloying elements to the extent of more than 40 per cent. It has a tensile strength of about 43,000 lb. per sq. in. and a hardness, as-deposited by oxyacetylene welding, of 62 Rockwell C. When deposits are heat treated by heating to 1950° F. and then air-cooling, the hardness reaches 66 to 67 Rockwell C.

Haynes "93" rod is available from Haynes Stellite Company, Kokomo, Indiana, and from resellers everywhere.

ROEBLING

the custom-made wire for exacting welders

★ BARE WELDING ELECTRODES

★ COVERED WELDING ELECTRODES

★ GAS WELDING WIRE

ROEBLING WELDING CABLES:

Made in a complete line of rubber and braided types for arc welding purposes.

JOHN A. ROEBLING'S SONS COMPANY, TRENTON, N.J.
Branches in Principal Cities

ONLY A FINE PRODUCT MAY BEAR THE NAME ROEBLING

REVIEW OF RESISTANCE WELDING CONTROL DEVELOPMENTS 1939

By E. H. Vedder*

The year 1939 has shown very rapid expansion of the use of electronic control, especially in the automotive, aircraft and rail car industries. Approximately 500 electronic contactors have been installed by Westinghouse alone, their popularity being brought about by reduced maintenance and more accurate welding. Most of these are in the automotive industry.

In aircraft manufacture, the trend toward welding metal planes continues. Resistance welding is now recognized as reliable enough to use on stressed parts of wings and fuselage. Ignitron welding timers are used on the aluminum and stainless steels normally welded in aircraft. A complete sequence panel has been developed to provide accurate sequencing of the welder and welding timer. The panel also contains complete apparatus for overload protection as shown in Fig. 1.

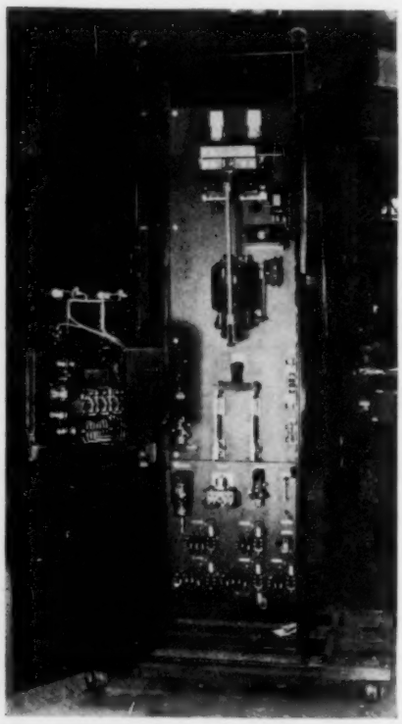


Fig. 1—A Sequence and Protective Panel for Aircraft Welding Which Provides "Squeeze," "Weld," "Hold" and "Off" Times, Combined with Complete Circuit and Control Protection

The sequence timers are shown mounted on the door, while the electrically operated breaker and disconnect switch is on the upper panel with small control breakers.

In order that consistent welding may be insured, it is necessary to know that the current and time of the weld are constant. The instrument panel in Fig. 2 gives an audible indication if the current and time, or either, vary outside desired limits. The air pressure at the welding electrodes is also indicated by the gage.

A panel mounted electronic contactor has been developed for steel mill application (Fig. 3). It includes heat control and thermostatically controlled cabinet temperature to avoid freezing of water in the tubes. This unit is rated 880 amperes continuous, or 1500 amperes for 3 seconds, 60 per cent duty of 2800 amperes for 1.5 seconds, 30 per cent duty or 5300 amperes for 0.5 second, 10 per cent duty.

* Electronics Division, Westinghouse Electric & Manufacturing Company, East Pittsburgh, Pa.

Fig. 2—An Instrument Panel with Weld Comparer Which Indicates Audibly a Deviation from Normal of Welding Time or Current Together with Pressure Gage and Ammeter

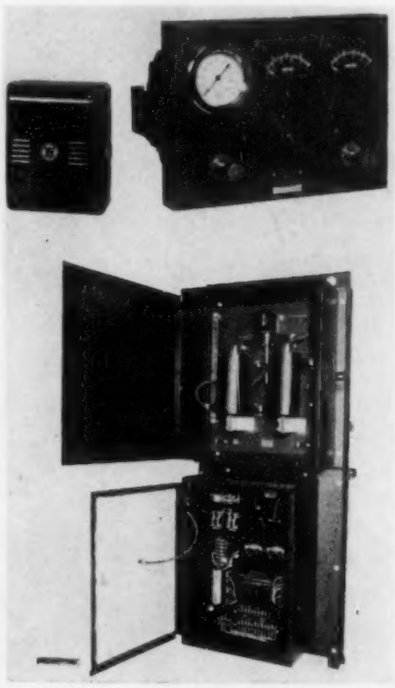


Fig. 3—A Panel-Mounted Electronic Contactor for Steel Mill Use

A COLD TINNING COMPOUND FOR ALUMINUM

This new tinning compound for aluminum makes the use of tin-lead solder to be sprayed on to aluminum as simple as *A B C* and eliminates special aluminum solders and fluxes.

With this new tinning compound, it is claimed, the surface to be tinned is prepared in the usual way. A clean rag, moistened with water is then dipped into the compound and rubbed over the surface to be tinned until a shiny metal coating is formed. This coating then forms a permanent bond with the tin-lead solder which is sprayed on thereafter.

Further details may be obtained by writing direct to the manufacturer, Glaser Lead Co., Inc., 29–31 Wyckoff Ave., Brooklyn, N. Y.

BULLARD SAFE-WELD HELMET

It's a helmet built as the welder wants it. Snug—light weight—compact and comfortable—the Bullard Safe-Weld Helmet is but little larger than the head and approximately 5 inches smaller than a fiber helmet. Thus, it is particularly adapted to welding in small space.

The entire head is protected by the helmet. Even when the leather is folded back for added ventilation for surface or shop welding, back light and flashes are excluded by the welding goggles, held comfortably in place in any head position by the "live rubber headband." Super-tough welding lenses of any desired shade give complete eye protection from both welding light and sparks, and metal particles.

LIGHT GAGE METAL WELDING AND CUTTING OUTFIT

The welding of light gage metals in the aeronautical, body and fender and sheet metal industries requires a welding outfit of more than customary excellence.

Paramount for accurate flame maintenance and control are two stage reduction regulators designed for exceptional pressure accuracy and freedom from "freezing." The welding torch should be of proper dimensions and weight distribution to facilitate ease of operation. Within the more limited scope of necessary flame sizes a larger than usual nozzle size selection should be offered.

With these considerations in mind, Victor Equipment Company, 844 Folsom St., San Francisco, now offer a new Aeroplane Welding and Cutting Unit.

Each welding torch nozzle is provided with its integral and Victor-patented gas mixing device properly controlling gas ratios and exit velocities. The cutting attachment can be fitted on to this welding torch butt instantly and offers a cutting range of metal diameters up to $2^1/_2$ inches.

BUTT WELDING

One of the most important applications of resistance welding is that of butt welding. By this method, rods, bars, shapes and sheets in an almost unlimited variety are welded together. Some of the most common applications involve the welding of dissimilar metals such as tool steel to common steel, forgings and steel castings to bars, etc.

Butt-flash welds are in nearly every case equal in strength to the parent metal, and in many cases, the physical properties are superior.

New uses for this method of welding are being applied daily. Are you giving it full consideration in your manufacturing methods?

Resistance Welder Manufacturers' Association

505 Arch Street — Philadelphia, Pa.

MEMBER COMPANIES

Acme Electric Welder Company, Los Angeles
American Electric Fusion Corporation, Chicago
Eisler Engineering Company, Newark, N. J.
Expert Welding Machine Company, Detroit
Federal Machine and Welder Company, Warren
Multi-Hydromatic Welding and Manufacturing Co., Detroit, Mich.
National Electric Welding Machines Co., Bay City
Progressive Welder Company, Detroit
Swift Electric Welder Company, Detroit
Taylor-Hall Welding Corporation, Worcester
Taylor-Winfield Corporation, Warren
Thomson-Gibb Electric Welding Co., Lynn
Welding Machines Mfg. Company, Detroit

ASSOCIATE MEMBER COMPANIES

P. R. Mallory and Co., Indianapolis
S-M-S Corporation, Detroit
Electroloy, Inc., New York
Welding Sales and Engineering Co., Detroit

» » » SECTION ACTIVITIES « « «

CHATTANOOGA

The Chattanooga Section of the AMERICAN WELDING SOCIETY held its regular monthly meeting on Tuesday evening, January 11th, at the Hotel Patten. The principal speaker of the evening was Captain George M. Enos, Associate Professor of Metallurgy at the University of Cincinnati. His subject was "The Visual Examination of Steel," or "What Can Be Learned About Steel with Inexpensive Equipment." His address was well illustrated with lantern slides, and covered such topics as (1) Examination of fractures, (2) Deep-etch tests on steel and (3) Special methods of macroetching.

A dinner meeting and roundtable discussion was held before the regular meeting.

CINCINNATI

The regular monthly meeting of the Cincinnati Section was held on December 13th. Mr. C. H. Jennings of the Westinghouse Electric & Manufacturing Company spoke on "Distortion Problems in Welding" and timeliness of the subject brought an attendance of 76 persons to this meeting.

The next meeting will be held January 10th when Mr. L. C. Bibber of Carnegie-Illinois Steel Company will be the speaker.

The Cincinnati Chapter has enjoyed an increase in membership and a new and renewed interest among prospects and present members which is attributed to the national business upswing as well as the forward steps welding has taken in the past few years in the minds of laymen and the economics of it that have been brought to the attention of management.

CLEVELAND

The regular monthly meeting of the Cleveland Section was held on January 10th at Fenn College. Mr. Abraham Grodner, Chief Engineer of Process Equipment Department of Blaw-Knox Division, Pittsburgh, presented the talk originally scheduled to be given by Mr. E. W. Forker, Manager of Process Equipment Dept. The subject of the talk was "Manufacture of Process Machinery by Arc and Hammer Welding and Gas Cutting."

DETROIT

At the January 5th meeting of the Detroit Section, Mr. G. C. Mikhalapov, Welding Engineer, Baldwin-Southwark Corporation, Philadelphia, presented an interesting address on "The Importance of Fundamental Research in Resistance Welding."

GEORGIA

On the evening of December 8th, the Georgia Section gave a social at the Atlantic Beer Company, in the Tap Room for the Benefit of prospective and active members.

NEW YORK

The New York Section, AMERICAN WELDING SOCIETY and the Metropolitan Section, American Society of Civil Engineers held a joint technical meeting on Wednesday, December 20th, 1939 at 7:45 P.M. in Room 501 of the Engineering Societies Building, 33 W. 39th Street, New York, N. Y. The Chairman was Mr. George W. Burpee, Partner, Coverdale & Colpitts, Consulting Engineers and President, Metropolitan Section, A.S.C.E. The session opened with the introduction of Mr. L. S. Moisseiff, Vice-President of the AMERICAN WELDING SOCIETY, who introduced Dr. C. A. Adams, the only living Honorary Member of the AMERICAN WELDING SOCIETY, who had been selected by the Board of Directors to make the presentation of a certificate of Honorary Membership in the AMERICAN WELDING SOCIETY to Mr. F. T. Llewellyn. Mr. F. T. Llewellyn spoke a few appropriate words of acceptance.

The first technical paper, entitled "Structural Welding in the Tacoma-Narrows Bridge" was presented by Mr. Jonathan Jones, Chief Engineer, Fabricated Steel Construction, Bethlehem Steel Company. Mr. Jones described the structural weldments which were substituted for the usual steel castings for the cable bands and cable saddles, as well as for the strand shoes of the 2800-ft. suspension bridge. His talk was well illustrated by lantern slides.

The second technical paper on "Shear Tests of Plug and Slot Welds" was presented by Mr. C. E. Loos, Manager, Structural & Plate Bureau, Metallurgical Division, Pittsburgh, Carnegie-Illinois Steel Corporation. Mr. F. H. Dill, Assistant to Chief Mechanical Engineer, American Bridge Company, Co-Author of this paper, was also present. The paper was illustrated by a number of good lantern slides. This joint paper describes tests made to determine safe working stresses for plug and slot welds. It also discusses the behavior of joints connected by both plug welds and fillet welds.

Following the papers, there was a very interesting discussion after which refreshments were served. In spite of the nearness of the Christmas Holiday and the inclement weather, approximately 475 persons attended the meeting.

The meeting was preceded by an American Welding Society Dinner in honor of Mr. F. T. Llewellyn. A special program had been prepared for this dinner which went off very successfully and was much enjoyed by everybody present.

Participating in the ceremonies were Messrs. C. A. McCune, F. M. Farmer, A. G. Oehler, all past-presidents of the Society, and Messrs. P. W. Swain and Milton Male.

The New York Section, AMERICAN WELDING SOCIETY, held a Technical Meeting on Tuesday, January 9th, 1940 at 7:30 P.M. in Room 502 of the Engineering Societies Building, 33 West 39th Street, New York, N. Y. The Chairman was Mr. Charles Kandel, President, Craftsweld Equipment Corporation and Chairman, New York Section, A. W. S. The first paper was on "Plate Edge Preparation for Welding" by Mr. Harry E. Rockefeller, Manager, Process Development Department, The Linde Air Products Company. Mr. Rockefeller gave a very interesting description of a number of recent developments in plate edge preparation, including U-grooving and simultaneous single bevel and nose, and double bevel and nose preparations.

The second paper on "Gas Machine Cutting and Shipbuilding" was by Mr. Harry W. Pierce, Supervisor of Welding, New York Shipbuilding Corporation, Camden, N. J. The introduction to Mr. Pierce's paper was on general uses of flame cutting. This was followed by a discussion of the development of welded parts with gas machine cut preparation. Special applications and equipment were also described.

Both these very outstanding talks were well illustrated by lantern slides.

The attendance was approximately 235. The meeting was very successful and was much enjoyed by all present.

NORTHWEST

In the absence of Chairman T. J. Warmington, who was unavoidably unable to attend because of being out of the city, Vice-Chairman T. P. Hughes presided at the December 12th meeting of the Northwest Section.

He presented Robert F. Flood, Process Service Engineer, Central Division, The Linde Air Products Company, who showed the film "Unionmelt Welding" produced by his company, then gave a most interesting discussion upon the subject of "Oxy-Acetylene Cutting and Flame Hardening," illustrated by lantern slides. The technical program presented many valuable points which were greatly appreciated by the more than 100 members and guests in attendance.

Mimeographed references on "Metallic Arc Welding" and "The Welding of Cop-

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per and its Alloys," prepared by Vice-Chairman T. P. Hughes, Assistant Professor of Mechanical Engineering, University of Minnesota, were distributed.

Phil Brain's pictures of the 1939 Minnesota football team in action were shown at this meeting.

OKLAHOMA CITY

The regular January meeting of the Oklahoma City Section of the AMERICAN WELDING SOCIETY was held on the evening of January 5th in Parlor "A" of the Biltmore Hotel, with Chairman K. B. Banks presiding. Chairman Banks started the meeting with the showing of a motion picture on the Evolution of the Oil Industry. This picture, secured from the Bureau of Mines, was made in cooperation with the Sinclair Refining Company and showed the development of the oil industry from the time oil was discovered on pools by the Indians, through the early developments in Pennsylvania and up to the present time.

At the end of the picture Program Chairman O. T. Barnett introduced Mr. E. W. P. Smith, Consulting Engineer, Lincoln Electric Company, Cleveland, Ohio. Mr. Smith spoke on "Expansion and Contraction." He stressed the welding of plate and shapes toward the free end, pointing out the importance of the skip-back procedure in welding to avoid distortion due to expansion and contraction.

There were 40 men in attendance at this meeting including guests. This, we felt, was an unusually good turnout considering the weather and a tribute to the efforts of our Program Chairman in securing such interesting speakers and topics for discussion.

PEORIA

The Peoria Section held its annual business meeting at the Jefferson Hotel in Peoria, January 10, 1940. New officers for the coming year were installed and the report of the annual activities, treasurer's report, membership committee report, and chairman of the program committee report were heard in the progress of the business program. The Chairman, Mr. Elmer E. Isgren, then presented an address on "The Outlook for the Welding Society in 1940."

The new officers for the Peoria Section for 1940 are as follows: Chairman, Mr. Elmer E. Isgren, R. G. LeTourneau Inc., Peoria, Ill., who continued from last year for another year; Vice-Chairman, Mr. G. A. Sively, Sommer Products Co., Bartonville, Ill.; Treasurer, Mr. Clifford Wimmer, Keystone Steel and Wire Co., Peoria, Ill.; Secretary, Mr. Albert A. Losch, R. G. LeTourneau Inc., Peoria, Ill. The new directors to serve two years are Mr. W. I. Miskoe, Lincoln Electric Co., Peoria, Ill.; Walter J. Brooking, R. G. LeTourneau Inc., Peoria, Ill.; Lyell Hardbarger, R. G. LeTourneau Inc., Peoria, Ill. The directors who will continue their services for the next year are Mr. John F. Resist, Keystone Steel & Wire Co., Bartonville, Ill.; Mr. Arthur G. Filker, Reliance Welding Co., Galesburg, Ill.; and Mr. Robert R Rutledge of A. Lucas & Sons, Peoria, Ill.

About fifty members were present for the meeting.

PHILADELPHIA

Mr. T. McLean Jasper of A. O. Smith Corporation, Milwaukee, addressed the January 15th meeting of the Philadelphia Section on the subject "Modern Welding and its Development."

Meetings scheduled for the next few months to be held at 8:00 P.M., on the dates mentioned at the Engineers' Club, Philadelphia.

February 19, 1940—Welding of Copper Base Alloys, by I. T. Hook, Research Engineer of American Brass Company; Also "Flame Cleaning" by a representative of the Air Reduction Sales Co.

March 18, 1940—Fabrication of Pressure Vessels by Welding, by a representative of The M. W. Kellogg Co.

April 15, 1940—Welding in Marine Industry, by a representative of the American Bureau of Shipping.

May 20, 1940—Inspection trip.

PITTSBURGH

Mr. G. O. Hoglund, Engineer of the Aluminum Company of America, New Kensington, Pa., was the speaker at the January 17th meeting held in the Mellon Institute of Industrial Research. Mr. Hoglund's talk was on the subject "Gas, Arc and Resistance Welding and Brazing Methods as Applied to the Aluminum Alloys." The talk was illustrated with slides and sound films. The film showed the method used in production and fabricating plants for producing the various commercial forms of aluminum and its alloys.

PUGET SOUND

Dr. V. N. Krivobok, Associate Director of Research, Allegheny Ludlum Steel Corporation and one of the country's leading authorities on the subject of stainless steel, presented an illustrated discussion on the welding and manufactured methods employed with the new alloys. Dr. Krivobok spoke at a joint meeting of the Puget Sound Chapter of the American Society for Metals and Puget Sound Section of the AMERICAN WELDING SOCIETY on December 22nd at the Gowman Hotel.

ROCHESTER

On January 4th at Todd Union, University of Rochester, Mr. A. N. Kugler of the Air Reduction Sales Company, spoke on "Oxy-Acetylene Welding."

ST. LOUIS

Mr. H. C. Boardman of the Chicago Bridge & Iron Co., addressed the January 12th meeting of the St. Louis Section, on "A. W. S. Standard Qualification Procedure." This talk covered the revised rules, A. W. S. Standard Qualification Procedure, Section I, Manual Arc & Gas Welding as revised October 1939.

SAN JOAQUIN VALLEY

At the December 15th meeting of the San Joaquin Valley Section held in El Trejon Hotel, a Girls Double Trio, under the direction of Miss Cassidy, Musical Director, Kern County Union High School, presented a musical program of Christmas selections.

The business part of the meeting was participated in by Mr. Roy Hanson, President, Roy Hanson Mfg. Co., Los Angeles, who spoke on "The Manufacture of Butane Tanks and Equipment," and by Mr. Turner C. Smith, Chief Engineer, General Petroleum Corp., Los Angeles, who spoke on "Liquified Petroleum Gases in Industry." A special invitation was presented to the ladies to attend this meeting.

SOUTH TEXAS

The December meeting of South Texas Section was held on the 8th in the auditorium of the Elks Lodge, Houston. Mr. Leon C. Bibber, Welding Engineer of Carnegie-Illinois Steel Corporation, lectured and showed slides of "Welded Joints—Which Ones to Use, When and Why."

At the Annual Meeting held on December 29th the following officers were elected:

Chairman—B. W. Farquhar, Gulf Oil Corp.

Vice-Chairman—G. W. Woods, Hughes Tool Co.

Secretary-Treasurer—Tom Ketchbaw, Industrial Welding & Testing Lab.

Directors and Executive Committee—Ray C. Bender, Thomas Kegg, Gil V. Dye, W. C. Leahy, E. C. Jackson and L. H. Courtright.

YORK-CENTRAL PA.

The third monthly meeting of the York-Central Pa. Section was held on Monday evening, December 18th. The speaker of the evening was Dr. W. G. Theisinger who occupies the position of Welding and Metallurgical Engineer for the Lukens Steel Company at Coatesville, Pa. The subject was "Heat Effect in Welding." Dr. Theisinger had many fine slides but the highlight of the evening was a new film which was recently developed by Everett Chapman, President of Lukens Steel Company. This film entitled "Heat and Mechanical Stresses in Welding" gave us a very good idea of what takes place in metal when the arc welding process is applied. To proximate the conditions of the arc on steel, a cigarette lighter was used on bakelite specimens. One, to see clearly how stresses are set up and also the results of stress relieving. Dr. Theisinger proved to be a very interesting speaker and the ninety men who attended were well repaid.

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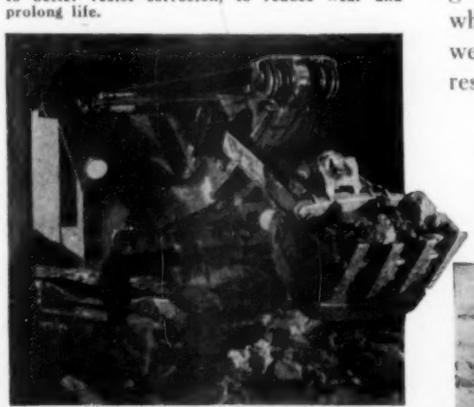
Snow flies off the road when this plow goes into action. By using special steels in strategic places, the Roto Wing Company was able to save 1000 pounds in deadweight without sacrificing strength in their new snow plow. The unit shown weighs less than 1300 pounds as against a former 2300-pound structure made from structural quality plates. 12-gauge U·S·S MAN-TEN was used for the mouldboard and 3/16" MAN-TEN for bracing back of the wing portion.

U·S·S COR-TEN used extensively in vast project to reclaim Everglades. Here's one of the 60 gates which shut out salt water and keep the fresh water level right for farming in the Dade County water control development in Florida. 936 linear feet of 72" culvert pipe, 26 swing gates and four turbine pumps, each with a capacity of 80,000 gallons, used in this project, were built of COR-TEN to better resist corrosion, to reduce wear and prolong life.



Shovels take a beating moving limestone rock. When equipment like this is built for gruelling work, designers know that Rolled Steel construction, with the use of special steels in the vital parts, will make it stronger and longer-wearing. Here, special steels and welded construction add to shovel life, keep the dipper from wearing out so quickly, and make the dipper boom stronger.

Look for this trade-mark on steel products. It is your assurance of quality and full value for your money.

Stands the Gaff!

Saves time and money, does more work, lasts longer in equipment that moves snow, mud, water and limestone rock

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Here again as in many other types of equipment, both heavy and light, performance proves that far more satisfactory results are obtained with welded, rolled steel construction. By using rolled steel, you can put special steels where they will do the most good and by so doing, add strength where you want it without increasing weight . . . and give vital spots extra resistance to impact, wear, heat, corrosion, abrasion and vibration.

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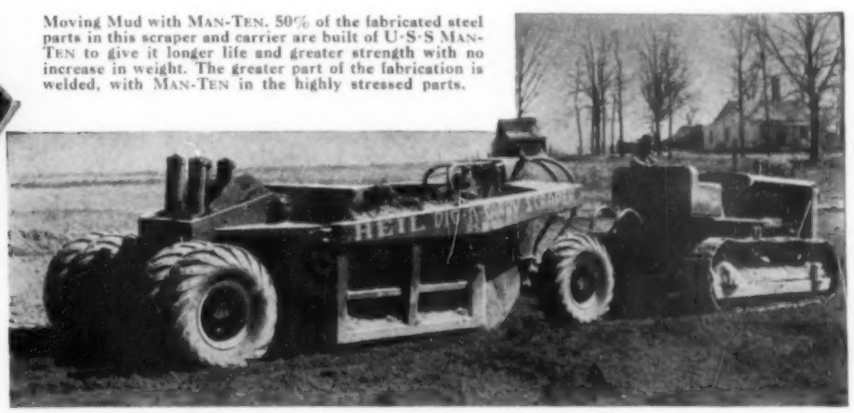

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A-334. Research Engineer available. A graduate engineer with degrees from University of Illinois and Lehigh University will be available shortly. During the past year he specialized in welding research. He was one of the brightest students in the Metallurgical class of the University of Illinois and Lehigh University. He is persevering, alert and of a likeable personality.

A-335. Expert Certified Aluminum Welder, 17 years' experience, would like supervising job on aluminum welding. Also certified Acetylene, Arc, Atomic Hydrogen Welder, hand and machine cutter. Age 35. Will supply more information.

A-336. Combination Welder. 3 years' experience as welder and cutter in the Maintenance Department of steel mill. Familiar with pipe welding, hard surfacing, brazing and cast iron welding. Age 27, single.

A-337. Welder with three years' experience; two years on strip mills construction for Rust Eng. Co., one year on new construction for Republic Iron and Steel. Attended Youngstown College, John Huntington Polytechnic and Lincoln Electric, majoring in Welding. Single, can go anywhere.

A-338. Young man, 25, with varied practical welding experience and good educational background, desires to make contact for position in welding research work. Some research experience.

A-339. Young man, high school graduate, just finished course in Gas and Electric Welding at the New England Welding Lab., wishes position as welder. Will go anywhere. 29 years of age, married.

BELMONT OFFICERS

The Directors of Belmont Iron Works have made the following corporate changes, effective January 1, 1940:

JOSEPH G. SHRYOCK, President and Chief Engineer; a graduate of the Pennsylvania Military College, 1900; came to Belmont in 1904; was appointed Chief Engineer in 1922 and later made Vice-President, Chief Engineer and Sales Manager.

JOHN A. MITCHELL, Vice-President and General Manager; graduate of University of Pennsylvania—class of 1912; rose to the position of Superintendent of the Eddystone plant and then Production Manager of all plants, which position he held at the time of this corporate change.

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This handy volume, suitable for the pocket, includes as much data as possible on various phases of welding. The information is condensed and diagrams are used wherever possible.

CONTENTS: Tables, Electric Arc Welding; Electric Arc as Maintenance Tool; Electric Arc Cast-Iron Welding; Planning a Welding Shop; Electric Resistance Welding; Resistance-Welding Machines, Projection Welding; Settings for Resistance; Seam and Butt Welding; Electric Brazing; Automatic Welding; Oxy-Acetylene Welding; Oxygen Cutting; Thermit Welding; Protection for Welders; Testing for X-Rays; Method of Testing Welds. The Chemical Publishing Company, 148 Lafayette St., New York City.

List of New Members

November 22nd to December 31, 1939

BOSTON

Bush, Stanley (D), 164 North Ave., No. Abington, Mass.
Dexter, Louis I. (B), The James H. Tower Iron Works, Providence, R. I.
Foley, John V. (B), Walworth Co., First & O Streets, So. Boston, Mass.
Galvin, Ernest E. (B), Walworth Co., 798—1st St., So. Boston, Mass.
Jones, Elisha (B), 77 Kalmar St., Worcester, Mass.
Macaulay, Harvey L. (C), 270 Dorchester Ave., So. Boston, Mass.
Ratzburg, Paul (D), 127 Cambridge St., Allston, Mass.
Russell, Warren K. (C), 9 Dewar St., Dorchester, Mass.
Sharp, Raymond E. (D), R. F. D., Rockland, Mass.
Webb, Wylie (D), 336 Amory St., Jamaica Plain, Mass.
Wilson, Francis W. (C), Wilson Engineering Corp., Harvard Square, Cambridge, Mass.

CANADA

Verch, Allen A. (D), 48 Alexandra Ave., Waterloo, Ont., Canada.

CHICAGO

Anderson, Harry (D), 9649 Forrest Ave., Chicago, Ill.
Designa, Americo (D), 15825 Lathrop Ave., Harvey, Ill.
Dillon, Walter (D), 11838 Lafayette Ave., Chicago, Ill.
Franklin, R. J. (C), Chicago Hardware Fdy. Co., No. Chicago, Ill.
Gasper, Eugene D. (B), 120 W. 107th St., Chicago, Ill.
Goldsby, Fred L. (B), 9640 Cook Ave., Oak Lawn, Ill.
Heimback, Harold (D), 7200 So. Wood St., Chicago, Ill.
Hodges, Hubert E. (D), 216 Hickory Rd., Lombard, Ill.
Lindquist, Art (D), 31 East 119th St., Chicago, Ill.
Mann, Arthur S. (B), Paramount Textile Machinery Co., Kankakee, Ill.
Neill, N. R. (D), 7605 So. Union Ave., Chicago, Ill.
Orr, C. M. (B), Chicago Bridge & Iron Co., 1305 W. 105th St., Chicago, Ill.
Shields, Julian W. (B), Chicago Bridge & Iron Co., 1305 W. 105th St., Chicago, Ill.
Urban, John (D), 12428 Harvard Ave., Chicago, Ill.

CINCINNATI

Harbin, L. N. (C), 3751 Montgomery Rd., Norwood, Cincinnati, Ohio.
Jones, Harold O. (C), Air Reduction Sales Co., Dayton Industries Bldg., Dayton, Ohio.

CLEVELAND

Aldrich, W. H. (C), The Cleveland Elec. Illum. Co., 75 Public Square., Cleveland, Ohio.
Carson, Gordon B. (C), Case School of Applied Science, Cleveland, Ohio.
Copeland, H. Stewart (D), 9905 Platt Ave., Cleveland, Ohio.
Crowley, J. C. (C), The Dill Mfg. Co., 694 E. 82nd St., Cleveland, Ohio.
Haglund, L. E. (C), R.D. 3, Elyria, Ohio.
Knebusch, Herman (C), 657 E. 91st St., Cleveland, Ohio.
Loweth, F. C. (C), The Cleveland Elec. Illum. Co., 75 Public Square, Cleveland, Ohio.
Rader, W. E. (C), The Cleveland Elec. Illum. Co., 75 Public Square, Cleveland, Ohio.
Rolf, Raymond L. (C), The Lakeside Steel Improvement Co., 5418 Lakeside Ave., Cleveland, Ohio.

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Beeler, Eugene W. (C), P.O. Box 4531, Columbus, Ohio.
Burckholter, R. M. (D), Ohio Power Co., Philo, Ohio.
Eppley, W. C. (D), Ohio Power Co., Philo, Ohio.
Kassell, G. B. (D), 105—9th St., Zanesville, Ohio.

CONNECTICUT

Horan, Thomas F., Jr., (D), Niantic River Rd., Waterford, Conn.

DETROIT

Last, Albert J. (C), Welding Sales & Engineering Co., 1627 W. Fort St., Detroit, Mich.
Schonvizner, Michael S. (C), Welding Sales & Engineering Co., 1627 W. Fort St., Detroit, Mich.
Spice, Stuart M. (C), 1518 Lapeer Rd., Flint, Mich.
Warren, Harold B. (B), Thomson-Gibb Elec. Welding Co., 4—120 General Motors Bldg., Detroit, Mich.

INDIANA

Brown, Harold (D), 2147 Madison Ave., Indianapolis, Ind.
Canganelli, Benny (D), Pittsboro, Ind.
Scheuring, C. E. (B), Emerson-Scheuring Tank Co., Indianapolis, Ind.
Scheuring, Frank (C), 3480 Hillside Ave., Indianapolis, Ind.
Swinford, M. E. (C), Emerson-Scheuring Tank Co., Indianapolis, Ind.

KANSAS CITY

Carlson, Glenn A. (D), 2454 Benton Blvd., Kansas City, Mo.

LOS ANGELES

Cadwell, Ralph K. (B), American Pipe & Steel Corp., 230 Date St., Alhambra, Calif.
Donohue, J. J. (B), 5700 Alameda, Los Angeles, Calif.
Julian, A. R. (C), 5700 So. Alameda, Los Angeles, Calif.
Kelly, W. E. (B), 402 So. Freemont, Alhambra, Calif.
Reavis, C. G. (C), Precision Welding Co., 5707 Bandera, Los Angeles, Calif.

MARYLAND

Garcia, J. F. (D), Box 245, R. F. D. 2, Baltimore, Md.

NEW YORK

Bryk, Henry D. (F), 538 E. 6th St., New York, N. Y.
Dolan, William (D), Foster-Wheeler Corp , Carteret, N. J.
Durney, Martin M. (D), Raritan Arsenal, Metuchen, N. J.
Feely, John (D), 1975 Bathgate Ave., Bronx, N. Y.
Graves, Roy C. (D), 136 Van Dyke St., Brooklyn N. Y.
Gruber, Alvin V. (C), Fort Hill V-Noge, Scarsdale, N. Y.
Mandell, Michael B. (C), 2877 Grand Concourse, New York, N. Y.
Marinke, Joseph (D), 167 Washington St., Jersey City, N. J.
McHugh, Thomas J. (B), 20–39—27th St., Astoria, L. I., N. Y.
Praeger, Emil H. (B), 66 Rugby Road, Brooklyn, N. Y.
Robertson, George (D), Foster-Wheeler Corp., Carteret, N. J.
Rossi, Boniface E. (B), 32–40—93rd St., Jackson Heights, L. I., N. Y.
Saacke, Frederic C. (C), Air Reduction Sales Co., 181 Pacific Ave., Jersey City, N. J.
Vitello, Peter A. (D), 45 E. Grand St., Rahway, N. J.
Walker, K. L. (D), Foster-Wheeler Corp., Carteret, N. J.

NORTHWEST

Baillon, Paul V. (C), B. W. Parsons Co., 1315 Minn. Mutual Life Bldg., St. Paul, Minn.

PEORIA

Rhode, Robert (D), 515—7th St., Peoria, Ill.
Zimmerman, C. F. (C), R. G. Le Tourneau, Inc., Peoria, Ill.

PHILADELPHIA

Barone, D. (D), 5124 Master St., Philadelphia, Pa.
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Simmons, Arthur (D), 236 Nevin St., Lancaster, Pa.
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Walling, Lloyd C. (B), Socony Vacuum Oil Co., Apartado No. 246, Caracas, Venezuela.
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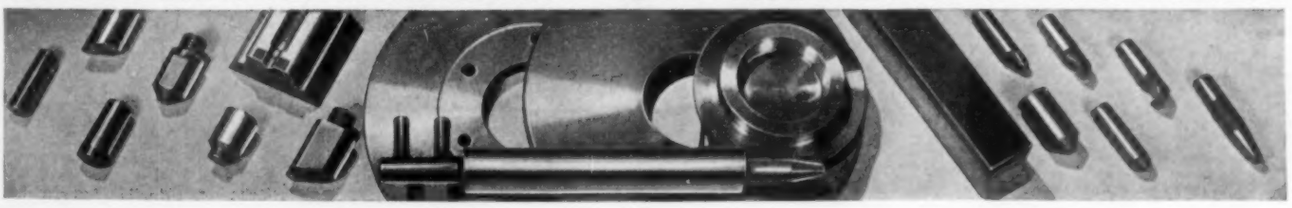

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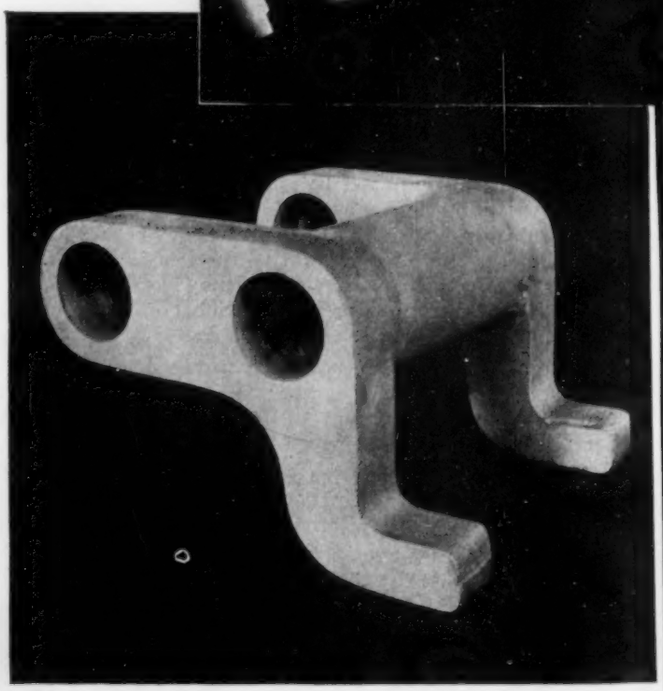

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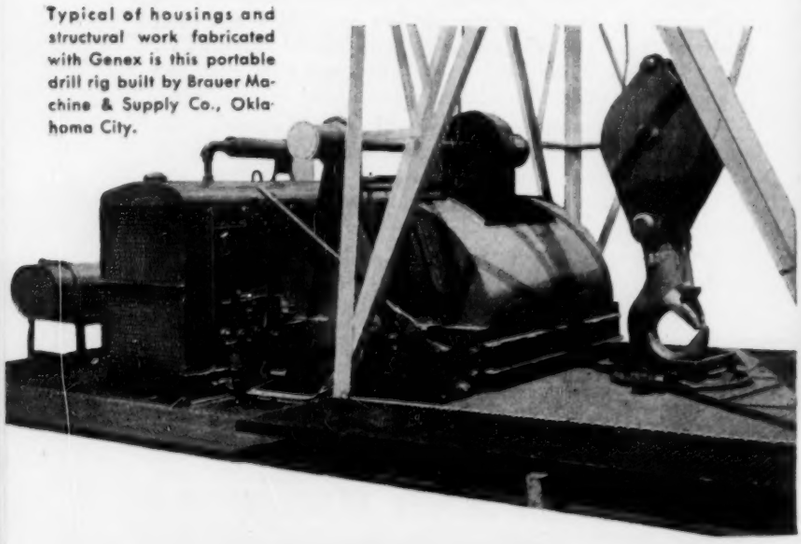

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